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# RIVER BIRDS OF PREY AREA

# 1991 ANNUAL REPORT

## Research and Monitoring

U.S. Department of the Interior

BUREAU OF LAND MANAGEMENT

Boise District, Idaho

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# SNAKE RIVER BIRDS OF PREY AREA RESEARCH AND MONITORING ANNUAL REPORT 1991

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NOT FOR PUBLICATION

The data presented herein are preliminary and may be inconclusive. Permission to publish or cite any of these materials is therefore withheld pending specific authorization of the Director of the Raptor Research and Technical Assistance Center, BLM, and the specific Principal Investigator.

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# PREFACE

This report summarizes research and monitoring activities in the Snake River Birds of Prey Area (SRBOPA) during calendar year 1991.

**BLM/IDARNG Research Project**

Field Studies: This was the first year of intensive field work for the 5 component studies of this 6-year research project (Table 1). Studies were at near full intensity with some 60 people in the field. Results of these efforts are presented in the first half of the progress reports of this volume.

Table 1. Component Studies of the BLM/IDARNG Research Project

| | |
|---|---|
| Study 1. | *Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas.* Tom J. Cade, Christine Watson, and Katherine Strickler, Principal Investigators. Raptor Research Center, Boise State University. |
| Study 2. | *Raptor Habitat Use and Foraging Behavior.* John Marzluff, Principal Investigator. Greenfalk Consultants. |
| Study 3. | *Raptor Nesting Densities and Reproductive Success.* Michael N. Kochert, Robert N. Lehman, and Karen Steenhof, Principal Investigators. Raptor Research and Technical Assistance Center, BLM. |
| Study 4. | *Townsend's Ground Squirrel Abundance, Productivity, and Habitat Relationships.* Beatrice Van Horne, Principal Investigator. Colorado State University. |
| Study 5. | *Vegetation Classification/Description and the Ability of Soils/Vegetation to Support Ground Squirrel and Jackrabbit Populations.* Steven T. Knick, Principal Investigator. Raptor Research and Technical Assistance Center, BLM. |
| Study Integration | John Rotenberry, Principal Investigator. University of California, Riverside. |

Project Integration: Principal accomplishments of the 1991 Integration effort include: forming a Technical Advisory and Review Panel (TARP), organizing a Project Integration Workshop, acquiring new computer hardware and Geographical Information System (GIS) software, developing a protocol for constructing the habitat map from satellite imagery, and review of 1991 annual reports and 1992 study plans for each component study. Final annual reports are presented in this volume, and revised versions of the 1992 study plans will appear as addenda to the original study plans in the 15 January 1991 Research Plan for the Project.

Because of the complexity of the Project and the need to ensure that results are as technically reliable as possible, a small panel of outside scientists was formed to assist in the review process. The TARP provides advice in evaluation, interpretation, and integration of data collected by the 5 component studies. The TARP also assists, as requested, with the technical review of study progress reports and study plans, study integration approaches, analytical and statistical techniques, and resulting publications, including National Environmental Policy Act documents. Panel members are:

Dr. Michael Collopy, BLM Cooperative Research Center, Corvallis, Oregon;

Dr. Brian Maurer, Brigham Young University, Provo, Utah;

Dr. Graham Smith, U.S. Fish and Wildlife Service Office of Migratory Bird Management, Patuxent, Maryland; and

Dr. Jay Anderson, Idaho State University, Pocatello, Idaho.

A project integration workshop was held in Boise on 19-20 November 1991. Principal investigators presented 1991 results and discussed any proposed changes in study designs for 1992. Project integration staff also described the goals and progress of the integration effort. The workshop concluded with a discussion of several specific issues raised by project investigators or that remained unresolved from the previous integration workshop. Major recommendations included an increased emphasis on completion of an accurate vegetation or habitat map of the study area and development of improved statistical techniques for several of our more complicated analyses. Several committees were formed to address particular issues that remained unresolved at the conclusion of the workshop.

To support development of a habitat or vegetation type map and to maintain the Digitized Resource Data Base Map, new computer hardware and GIS software were acquired. Hardware consisted of a Sun SPARCStation 2 workstation, whereas software consisted of ARC/INFO (Ver. 6.0) for vector-based data, and GRASS (Ver. 4.0) for raster-based data and image processing.

Because of severe deficiencies in the existing habitat/vegetation map identified at the 1990 Project Integration Workshop, a new protocol for producing such a map from satellite imagery was developed. The protocol is identified in the vegetation report (Knick et al., this volume).

**Other Research and Monitoring in the SRBOPA**

Work in the SRBOPA continued with cooperating universities in 1991. Dr. James Munger of Boise State University continued his kangaroo rat study and initiated pilot studies on harvester ants and Townsend's ground squirrel energetics and survival. Scott Grothe, a graduate student from Idaho State University, finished field work for his red-tailed hawk predation study, and Dr. Carl Marti of Weber State University continued investigations of common barn-owl feeding ecology.

RRTAC staff implemented certain studies and maintained cooperative efforts with other agencies, private industry, and individuals. RRTAC studies included assessment of nest box use by American kestrels by Karen Steenhof and the initiation of Global Climate Change research by Steve Knick. Another BLM study involved western screech-owl and northern saw-whet owl use of nest boxes in the SRBOPA by John Doremus of the Bruneau Resource Area. Helen Ulmschneider continued her study on long-eared owls, and RRTAC personnel again monitored raven roosting on the Pacific Power and Light Company (PP&L) line for PP&L. RRTAC also conducted a passerine bird survey of different habitats in the SRBOPA in cooperation with the U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center.

Monitoring activities also continued in the SRBOPA. Townsend's ground squirrel and black-tailed jackrabbit monitoring was part of Study 5 of the BLM/IDARNG Research Project. U.S. Army Corps of Engineers, CERL, again conducted monitoring activities in the Orchard Training area in cooperation with the IDARNG, and the Idaho BLM State Office also monitored greenstrips within the SRBOPA.

**Technology Transfer**

Although the main thrust for 1991 was implementation of the BLM/IDARNG Research Project and continuation of cooperative research projects, work still continued on Technology Transfer. Three scientific papers were published and/or accepted for publications in 1991, and BLM RRTAC staff and associates made 18 technical presentations at various meetings and workshops.

## ACKNOWLEDGMENTS

The Bureau of Land Management wishes to thank those agencies and individuals who assisted with the project. Appreciation is extended to the Idaho Department of Fish and Game and the U.S. Fish and Wildlife Service for special permits and assistance. Special thanks go to all other individuals who volunteered their services.

## COOPERATING AGENCIES AND INSTITUTIONS

Albertson's College of Idaho
Boise State University, Raptor Research Center
Colorado State University
Greenfalk Consultants
Idaho Army National Guard
Idaho Department of Fish and Game
Idaho Department of Transportation
Idaho Department of Water Resources
Idaho Power Company
Idaho State University
Pacific Power and Light Company
Peregrine Fund; World Center for Birds of Prey
University of Idaho
U.S. Army Chemical Engineering and Research Center
U.S. Army Corps of Engineers, CERL
U.S. Fish and Wildlife Service
  Office of Migratory Bird Management
  Patuxent Wildlife Research Center
  Boise Field Office
U.S. Forest Service Intermountain Research Station
Weber State University

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# PART I

# TECHNOLOGY TRANSFER

Snake River Birds of Prey Area
Technical Articles Published and/or Accepted for Publication

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* Published and/or accepted for publication in 1991. Reprints of most of these articles are available from the Raptor Research and Technical Assistance Center, Bureau of Land Management, 3948 Development Avenue, Boise, ID 83705.

1991 Birds of Prey Research Technical Presentations

01/23/91 Knick, S.T. Relationship between weather, fire patterns, and vegetation change in the Snake River Birds of Prey Area, Idaho. U.S. Department of the Interior Meeting on Global Climate Change Research. Denver, Colorado.

02/07/91 Grothe, S. Red-tailed Hawk predation on snakes: the effects of weather and snake activity. Idaho Chapter of The Wildlife Society. Annual Meeting. Boise, Idaho.

02/07/91 Ulmschneider, H. Food habits of the Long-eared Owl in southwestern Idaho: seasonal changes and comparisons of diets of adults and young. Idaho Chapter of The Wildlife Society. Annual Meeting. Boise, Idaho.

02/07/91 Holthuijzen, A.M.A. Behavior of nesting prairie falcons (*Falco mexicanus*). Idaho Chapter of The Wildlife Society. Annual Meeting. Boise, Idaho.

02/08/91 Steenhof, K. Bald eagle populations in the 7 western states: prospects for downlisting. Idaho Chapter of The Wildlife Society. Annual Meeting. Boise, Idaho.

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03/20/91 Grothe, S., C.R. Peterson, and C.H. Trost. Red-tailed Hawk predation on snakes: the effects of weather and snake activity. Northwest Scientific Association 64th Annual Meeting. Boise, Idaho.

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06/17/91 Yensen, E., D.L. Quinney, K. Johnson, K. Timmerman, and K. Steenhof. Townsend's ground squirrel population fluctuations in southwestern Idaho. American Society of Mammalogists 71st Annual Meeting. Manhattan, Kansas.

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10/10/91 Holthuijzen, A.M.A. Impacts of construction activities on nesting prairie falcons. 17th Annual EEI Biologists Task Force Workshop. Boise, Idaho.

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10/12/91 Vekasy, M., J. Marzluff, and M. McFadzen. Effects of radio transmitters on breeding prairie falcons. Annual Meeting of the Western Bird Bander's Association, Boise, Idaho.

11/7/91 Gossett, D.N., and M.J. Bechard. Morphological differences of ferruginous hawks in Alberta and Idaho. Annual Meeting of the Raptor Research Foundation. Tulsa, Oklahoma.

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11/7/91 Steenhof, K., and R.R. Spahr. Wintering bald eagle population trends in Idaho, 1980-1991. Annual Meeting of the Raptor Research Foundation. Tulsa, Oklahoma.

11/7/91 Vekasy, M., J. Marzluff, and M. McFadzen. Effects of radio transmitters on breeding prairie falcons. Annual Meeting of the Raptor Research Foundation. Tulsa, Oklahoma.

11/9/91 Marti, C.D., K. Steenhof, M.N. Kochert, and J.S. Marks. Trophic characteristics and guild structure of vertebrate predators. Annual Meeting of the Raptor Research Foundation. Tulsa, Oklahoma.

# PART II

# PROGRESS REPORTS

# Raptor Nesting Densities and Reproductive Success in the Snake River Birds of Prey Area, 1991

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*Annual Summary*

*The number of prairie falcon (Falco mexicanus) pairs (183) in the Snake River Birds of Prey Area (SRBOPA) was slightly lower than in 1990, but within the range observed in the late 1970's. Densities in selected 10-km stretches were below the long-term average. Occupancy of historical prairie falcon nesting areas was lowest in the "Orchard Training Area (OTA) shadow", but reproduction within the "shadow" did not differ significantly from that east or west of the shadow. Overall, prairie falcon productivity in the SRBOPA (3.3 young per pair) was the highest ever recorded in 18 years. At least 9 of the falcons radioed in 1990 were encountered during the 1991 nesting season. Nesting areas where birds had been radioed in 1990 had occupancy and success rates higher than or equal to those of randomly-selected nesting areas. Golden eagle (Aquila chrysaetos) nesting density in the SRBOPA was slightly lower than in 1990 and the preceding 3 years. Number of young eagles fledged per pair in the SRBOPA (1.03) was lower than in 1990 but higher than in the years 1984-1989. As in 7 of the previous 8 years, golden eagle reproduction was higher in the Comparison Area. Sixty-four occupied raptor nesting areas were found on the ISA benchlands. These included 8 ferruginous hawk (Buteo regalis), 8 northern harrier (Circus cyaneus), 30 burrowing owl (Athene cunicularia), and 18 short-eared owl (Asio flammeus) pairs. Relative abundance of benchland nesters was similar inside and outside the OTA. Multivariate analyses indicated that rock outcrops, artificial structures, badger burrow density, and the intensity of military vehicle tracking may be related to nest site selection on the bench. Transects appeared to be more effective than circular-plot surveys for locating benchland nests, but detection rates of the 2 methods did not differ significantly.*

## OBJECTIVES

1. Assess 1991 prairie falcon nesting density and long-term population trends in the SRBOPA, and compare 1991 falcon nesting densities inside and outside the OTA Shadow.

2. Assess prairie falcon nesting reproduction at preselected nesting areas, and compare estimates of productivity to long-term trends in the SRBOPA.

3. Compare prairie falcon nesting success, productivity, and fledging weights inside and outside the OTA Shadow.

4. Assess any carry-over effects of the 1990 radiotelemetry effort on prairie falcon nesting occupancy and reproductive success.

5. Compare 1991 golden eagle density and productivity in the SRBOPA and Comparison Area.

6. Report recoveries of banded raptors and assess preliminary information on nest site fidelity and breeding dispersal.

7. Assess the relative abundance and reproductive success of benchland-nesting raptors inside and outside the OTA.

8. Compare habitat and land use characteristics of occupied benchland-nesting areas to randomly-selected unoccupied areas on the bench.

## INTRODUCTION

The overall objective of Study 3 is to determine if nesting densities and reproduction of the major raptor species in the SRBOPA have changed over time and if any such changes can be correlated with military use and fire occurrence. In addition, the best long-term approach for monitoring raptor densities and productivity will be determined.

The 1991 field season was the first intensive year of the study and was based on the results of the 1990 pilot effort. Field work in 1991 emphasized Tasks 1, 2, 3, 5, and 6 of the Study 3 Plan (Kochert et al. 1991). Density and reproductive data were collected on golden eagles and ferruginous hawks for Task 4, but analyses have been deferred until accurate historical burn maps for the OTA can be developed. Presently the Raptor Research and Technical Assistance Center (RRTAC) has a cooperative study with Idaho Department of Water Resources to develop such a map from satellite imagery as part of the RRTAC Global Change Research Project (Knick, this volume). In 1991, Study 3 also examined any carry-over effects of the 1990 radio telemetry effort on prairie falcons.

## METHODS

### Prairie Falcon Nesting Density and Reproduction

Nesting Density.--In 1991, all stretches of the Snake River Canyon and the major side canyons within the SRBOPA (Hammett to Walters Ferry) were surveyed for prairie falcon nesting activity 3 times: once between 18 March and 13 April; once between 3 May and 5 June; and once between 3 June and 24 June. As in past years, some buttes and portions of side canyons (Walters Butte, Rock Cabin Springs, Castle Rock, Little Hole, Rattlesnake Spring, Flatiron Butte, Cindercone Butte, and Gill nesting areas) were excluded from the survey area and/or the density analysis.

During each month's survey, observers surveyed stretches of the canyon from standardized observation points, spaced at approximately 1-km intervals. Some side draws consisting of small or broken cliff were surveyed by walking; we also avoided surveys from fixed observation points when our presence would have disturbed other species of nesting raptors. Most observation points were located on the canyon floor so that observers could face the potential nesting cliffs. Observations were made from the canyon rim along a few stretches where the view was obscured from below. Each observation point was surveyed for 2 hr during each monthly survey, except in cases where the survey stretch was less than 1 km because of side draws or convolutions in the cliff. In these cases, survey time was proportionately less. Only 1 side of the canyon was surveyed from each observation point except in areas where the canyon was very constricted. Clusters of observation points were identified based on the number of points that could be surveyed by a 2-person crew in 3 days. Each month, clusters were surveyed in a randomly-selected order. Observers recorded nesting activity of all raptors and ravens in field journals and on 1:24,000-scale U.S.G.S. topographic maps. Black and white 1:24,000-scale 1987 aerial

photographs were used to plot nests and reproductive-related activity. A nesting area was considered occupied if territorial defense, courtship, or other reproductive activity was observed (U.S. Dep. Inter. 1990).

Results were analyzed for the entire SRBOPA and for 10-km stretches of the canyon delineated in U.S. Dep. Inter. (1979). Data were compared with years when surveys of the entire area were complete (1976, 1977, 1978, and 1990) and for certain 10-km stretches surveyed between 1978 and 1990. Nesting densities in each 10-km unit were analyzed in relation to the amount of available cliff area (as calculated by Bentley and Hardyman [1978] and presented in U.S. Dep. Inter. [1979]). Densities in the stretches immediately south of the Orchard Training Area (Units 7, 8, and 9; hereafter the OTA "shadow") were compared with stretches west, southwest, and southeast of the OTA.

Reproduction.--Prairie falcon nesting success and productivity in the SRBOPA were assessed for 3 treatment groups in 1991. Study 2 assessed reproduction at sites where they radioed adults in 1991, and Study 3 assessed reproduction at a randomly-selected sample of "control" nesting areas; i.e., those that had not been radioed in either 1990 or 1991. We also monitored reproduction at 18 nesting areas where falcons had been radioed in 1990 (see Clugston 1990) to test for possible "carry-over" effects of radios.

Prior to the nesting season, all historical nesting areas in the Integration Study Area (ISA) were stratified as east, west, or inside the "OTA shadow", and nesting areas were randomly assigned to Study 2 and Study 3. The order of random selection determined which nesting areas would be studied and which would be back-up sites. The target "control" sample size (based on power tests; Kochert et al. 1991) was 51 "control" nesting areas (15 from the OTA shadow, 18 from west of the shadow, and 18 from east of the shadow).

Monitoring of selected "control" nesting areas began in early March. All selected nesting areas were checked for occupancy during the pre-incubation period, and all were re-checked during the first density survey. Between early April and late May, nesting areas were observed from remote observation points to identify probable nesting scrapes. Each observation bout continued for 2 hr or until a nesting scrape could be located. Nesting areas were rejected if occupancy could not be confirmed by mid-April (after 6 hr of observation), and replacements were selected from the list in the original random order. During all surveys, observers recorded sightings of birds wearing colored leg bands. Nesting areas where falcons were radioed in 1990 were observed more intensively with both Questar and conventional spotting scopes during additional visits in an effort to determine whether marked birds had returned in 1991.

Nesting attempts were considered successful if 1 or more young reached 30 days of age (Steenhof 1987). Nestlings were aged at most nests by remote observations late in the brood-rearing period with the aid of an aging key (Moritsch 1983). Nest climbs were scheduled so that visits occurred when young were 30-35 days of age. To control for observer bias, measurements were taken by a limited number of people, all of whom had attended a seminar on standardizing measurement techniques. We exchanged personnel with Study 2 so that at least 30% of control broods were measured by Study 2 personnel, and at least 30% of broods with radioed adults were measured by Study 3 personnel. Young between 27 and 35 days of age were weighed, examined for condition, and banded with a U.S. Fish and Wildlife Service band on the right leg and a black anodized aluminum band with a unique alphanumeric code on the left leg. We also measured foot-pad length, tarsal width, and length of the seventh primary. Weights were adjusted on all birds whose crops were more than 25% full by subtracting estimated crop weights (BLM, unpubl. data). For the purpose of

analyses, birds with foot-pads > 86 mm were considered females, and those with foot-pads < 86 mm were called males.

To compare productivity among years, we used only 1991 "control" nesting areas and excluded nesting areas from previous years where experimental disturbances, nest site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment occurred. This was done to ensure that results were not biased by researcher manipulations. Analyses of percent of pairs successful and number fledged per pair were based on pairs selected for study prior to each nesting season. To assess the percent of nesting attempts that were successful, only those breeding attempts which were confirmed during incubation and for which outcome was known were included in the analysis. In both cases, number of young fledged per successful attempt was based on all pairs for which complete fledge counts were obtained.

**Golden Eagle Density and Reproduction**

In 1991, 38 traditional golden eagle nesting areas in the SRBOPA and 21 nesting areas in the Comparison Area (Fig. 1) were preselected for observation. All 59 nesting areas were surveyed by helicopter or from the ground in conjunction with other raptor surveys.

Helicopter surveys were conducted from a Bell 206 Jet Ranger on 14 March and 5 June. The purpose of the first survey was to determine if nesting areas were occupied and if eggs had been laid. Nesting areas containing breeding pairs were re-checked during the second flight to assess productivity. Helicopter surveys in the SRBOPA were conducted along the Snake River from Givens Hot Springs east to Glenns Ferry, and along the Pacific Power and Light (PP&L) transmission line from Miles 45 to 133. Helicopters were flown at speeds of 70-95 km/hr and we hovered approximately 10 m from nests for 5-25 sec to view nest contents. No attempt was made to flush incubating birds or count eggs. Nesting areas where occupancy or breeding status could not be ascertained during helicopter flights were subsequently surveyed from the ground. Ground surveys in 1991 were conducted in conjunction with prairie falcon density surveys in the SRBOPA and as independent efforts. Some nests in the Comparison Area were surveyed from the ground by Idaho Power Company personnel.

Eagle pairs that showed no evidence of egg-laying after repeated observations were categorized as "nonbreeding." A "breeding attempt" was confirmed if an occupied nesting area contained an incubating adult, eggs, young, or any indication that eggs had been laid (e.g., fresh eggshell fragments in fresh nesting material). A breeding attempt was "successful" if 1 or more young reached the age of 51 days (Steenhof 1987). A photographic aging key was used to age young (Hoechlin 1976). Eagle nests discovered after young had fledged were considered successful if: 1) a platform decorated this season was worn flat and contained fresh prey remains; 2) fresh fecal matter covered the back and extended over the edge of the nest; and 3) no dead young birds were found within a 50-m radius of the nest.

Percent of pairs breeding in 1991 and earlier years was calculated from preselected pairs (Steenhof and Kochert 1982). Percent of nesting attempts that were successful was based on attempts confirmed during incubation. Nesting areas where researcher manipulations (experimental disturbances, nest-site enhancements, manipulations of eggs or young, trapping and tagging, or disease treatment) had occurred were excluded from analyses of percent success.

**Nesting of Raptors on the Benchlands**

Relative Abundance.--To assess the abundance of raptors nesting on the benchlands north of the canyon, we searched randomly-selected plots inside and outside the OTA to locate occupied nesting areas. We used 2 types of sampling methods:

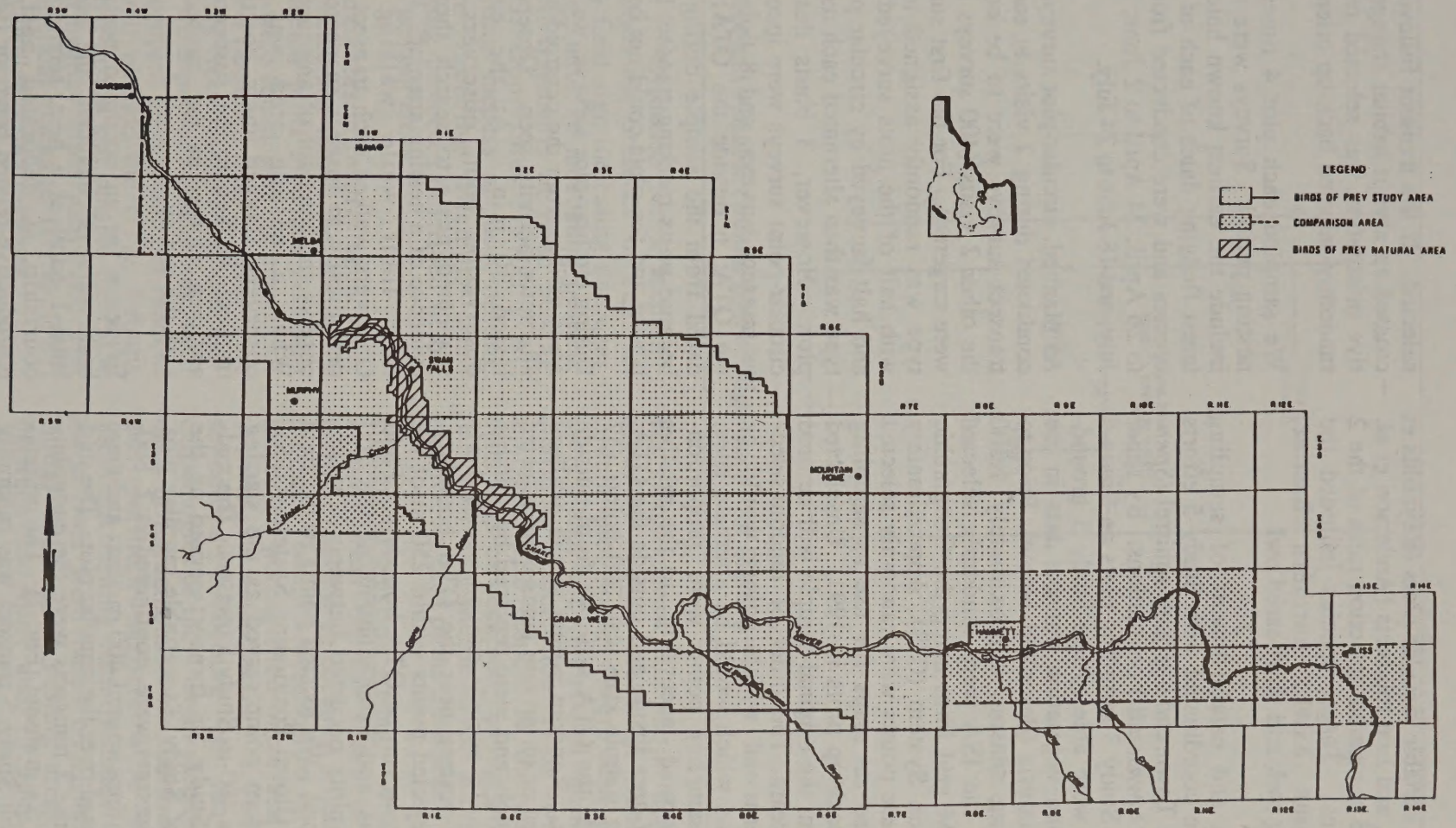


Fig.1. Location of the Birds of Prey Study Area (BPSA) and Comparison Area.

modified variable circular plots (Reynolds et al. 1980), and line transects (Anderson et al. 1979) and compared detection rates of the 2 approaches. Target species included the ferruginous hawk, northern harrier, burrowing owl, and short-eared owl.

Selection and establishment of sampling plots were coordinated with Study 5 efforts to sample Townsend's ground squirrel (*Spermophilus townsendii*) populations. By superimposing Study 3 sampling plots on Study 5 sites, we were able to use Study 5 ground-squirrel and vegetation transect data in the habitat analysis (described below). Prior to the nesting season, approximately 1,200 points in the ISA were randomly selected from UTM grid lines using the Geographic Information System (GIS). Approximately 400 of these points were randomly selected and plotted on maps for use as sampling plots or back-up plots in 1991. Unselected points from the original sample will be used in future years. The order of random selection determined which points would be studied and which would be alternate sites. Random sampling points were proportionately allocated according to the relative amount of area inside and outside the OTA. The target sample size was 200 points (57 from inside the OTA and 143 from outside the OTA). Random points in the artillery impact area or on private lands were rejected as study plots and were replaced by suitable alternates. To exclude canyon-nesting birds and birds nesting near the OTA boundary, we also rejected points within 250 m of the north canyon rim or OTA boundary. Field inspections and establishment of the 200 sampling plots occurred between 5 March and 24 April. We located points in the field using the Global Positioning System (GPS). Each random point served as the starting point of a 400-m Study 5 transect. The midpoint of Study 5's transect served as the centroid of Study 3's variable circular plot. Study 3 transects were configured as 2 800-m parallel lines spaced 400 m apart and were superimposed over the circular plot. The midpoints of the 2 transects were the endpoints of Study 5's transect (Fig. 2). The orientation of each Study 5 transect was randomly selected. If the transect followed a road or crossed an abrupt habitat change, an alternative orientation was selected from a list of randomly-selected back-up orientations.

We sampled each plot 4 times during the nesting period. Surveys were scheduled to include the earliest known hatch dates and latest fledging dates of each of the 4 target species and were conducted from 18 March to 26 April; 24 April to 2 June; 12 May to 2 July; and 18 June to 24 July.

As planned, circular-plot surveys were to be conducted during 2 visits at each plot, and transect surveys were to be conducted on the other 2 visits (400 surveys in each case were targeted). For the first survey, survey type was randomly assigned to each plot, with half of the plots surveyed by transect and half surveyed by circular plot. Survey type was then alternated each month at each plot. However, 3 bouts designated for circular-point surveys were incorrectly done as transect surveys, and 8 points (2 inside the OTA; 6 outside the OTA) were eliminated from the sample during the survey because posts marking transect lines disappeared and the plots could not be relocated.

During circular-plot surveys, we observed all areas visible from the centroid and recorded all raptor activity seen. Observation bouts lasted 30 min. At the end of each observation bout, observers walked to suspected nests to search thoroughly for evidence of a nesting attempt. There was no time limit while walking transects. Observers walked each transect and paused periodically to inspect suspected nests and observe the behavior of any raptors sighted. When a nesting area was suspected, observers flagged their position on the transect, walked to the suspected location, and then returned to the transect to proceed with the survey.

Evidence for an occupied nesting area on both surveys included the presence of at least 1 adult at a nest, territorial defense, courtship, a decorated nest, or other reproductive-related behavior (see U.S. Dep.

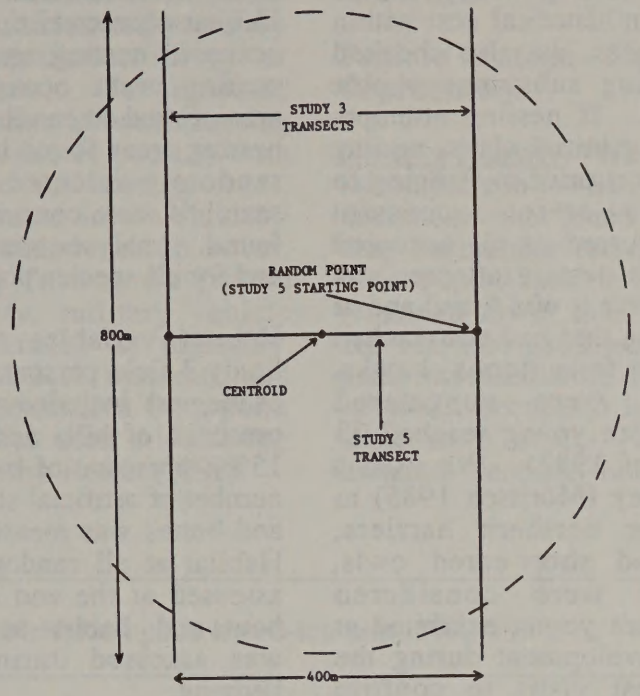


Fig. 2. Transect and variable circular plot configurations for Studies 3 & 5.

Inter. 1990). Evidence for a breeding attempt included the presence of eggs or young or any field sign indicating that eggs were laid (e.g., adult in incubating posture, fresh eggshell fragments in fresh nesting material--U.S. Dep. Inter. 1990). We assessed nesting success at most nesting areas where breeding attempts were confirmed using protocols described below for historical nesting areas.

To assess differences in relative abundance, we pooled species and tallied the number of randomly-selected plots at which occupied nesting areas were found, and the number of plots where no occupied nesting areas were found. Results from transect and circular-plot surveys were pooled to determine total number of occupied sites found per random site inside and outside the OTA. Groups were compared inside and outside the OTA using a contingency table analysis. The StatXact statistical package (Cytel 1989) was used to calculate exact p-values.

The effectiveness (i.e., rate of detection of occupied nesting areas) of transect and circular-plot surveys were also compared using a sign test. We pooled species for the analysis. Detection rates were also analyzed with respect to the number of detections of occupied nesting areas found per visit and the level of survey effort required for each of the 2 methods.

Historical Nesting Areas.--Of 64 raptor nesting areas on the ISA's benchlands known to have been occupied at least once in previous years, 63 were visited in 1991. Of these, 21 were visited once, and 42 were visited at least twice. Visits were scheduled according to the nesting chronologies of the 4 target species. Nesting dates of ferruginous hawks, burrowing owls, and northern harriers were based on SRBOPA nesting records; dates for short-eared owls were based on Linner (1980). Initial visits at all nesting areas occurred between 23 April and 17 June. Initial

searches at historical nesting areas involved a check of each known historical nest within the area. In some cases, we also checked other potential nesting substrates visible from historical nests. If nesting attempts were confirmed during initial visits, nesting areas were revisited just prior to fledging to determine if pairs were successful. Additional visits occurred at all occupied nesting areas where a nesting attempt was not confirmed at the time it was found and at those containing young that had not reached fledging age. For ferruginous hawks, breeding attempts were considered successful if 1 or more young reached 33 days of age (Steenhof 1987). We used a photographic aging key (Moritsch 1985) to age nestlings. For northern harriers, burrowing owls, and short-eared owls, breeding attempts were considered successful if 1 or more young exhibited at least 80% feather development during the last nest visit. Nest visits to confirm success continued through 30 July.

Other Nesting Areas.--To locate nesting areas not recorded previously, we followed up on all observations of reproductive-related activity involving any of the 4 target species reported by other study teams or observed by Study 3 personnel. If nesting activity was observed by Study 3 personnel while traveling in the ISA, observers conducted an immediate search of the area for evidence of a nesting attempt. We asked other study teams involved in BLM/IDARNG research to record observations of the target species on a standard data form during field operations. All nesting areas where breeding was confirmed were revisited later in the nesting season to determine nesting success. However, we were unable to determine nesting success at 3 sites though each was visited at least twice after the initial visit. Visits were scheduled according to the nesting chronologies of the 4 target species, as cited above for historical nesting areas, using similar protocols.

Habitat Assessments.--We used logistic regression to identify features associated with nest site selection on the benchlands. Habitat characteristics were described at 64 occupied nesting areas (including historical nesting areas occupied in 1991, nesting areas found at randomly-selected plots, and nesting areas found incidentally), and at 178 randomly-selected plots where nest searches were conducted but nests were not found. Analyses were done for each species and for all species pooled.

Habitat variables estimated ocularly by Study 3 field personnel within a 50-m radius of the nest included number of rock outcrops, presence of hills and buttes (with slopes > 15%), presence of banks and road cuts, and number of artificial structures. Slope of hills and buttes was measured with a clinometer. Habitat at all randomly-selected plots was assessed at the end of the last observation bout, and habitat at occupied nesting areas was assessed during a final visit after fledging.

Habitat characteristics obtained from the Digitized Resource Data Base Map (DRDBM) included military regime type, grazing regime type, and soil depth, land form, and soil development at the nest or random point. Military regimes were defined as: (1) firing areas (inside the Firing Impact Area); (2) firing and tracking areas (inside artillery position areas); (3) tracking areas (within the OTA but outside the previous 2 designations); and (4) non-military (outside the OTA). Grazing regimes were defined as: (1) spring-fall range (north of the drift fence) and (2) winter range (south of the drift fence). Soils data were obtained from Ada, Canyon, Elmore, and Owyhee County soil surveys (U.S. Dep. Agric. 1972, 1980, 1991, unpubl.). Soil depth was analyzed for 3 categories: shallow (< 51 cm), medium (51 - 102 cm), and deep (> 102 cm). Land form was classed as "basaltic" or "other", and soil development was considered either "strong" or "weak". We also calculated the proportion of each military regime within a 1-km radius of each nest or random point, with artillery position areas and the firing impact area combined into 1 category in the analysis.

We also performed a canonical discriminant analysis on habitat variables measured by Study 5 personnel during transect surveys at randomly-selected points. We compared characteristics of 12 points at which nesting areas were found (all species pooled) with 103 points which had no nesting areas. Habitat variables measured in the field by Study 5 personnel included shrub cover, total vegetative cover, Townsend's ground squirrel burrow density, military vehicle tracking intensity (estimated as presence/absence on segments of each transect), and percent track cover (as measured from point frames). Field procedures used in obtaining these data are described by Knick (1991).

## RESULTS

### Prairie Falcon Nesting Density and Reproduction

Nesting Density.--We identified 183 prairie falcon pairs in the SRBOPA in 1991, 2 fewer than the number found in 1990 and 1 more than the number found in 1978. The number of occupied prairie falcon nesting areas remained lower than 1976-77 levels when 205 and 206 pairs were found. Numbers of pairs increased from 1990 levels in 4 10-km stretches, decreased in 7, and remained the same in 6 others (Table 1). The most dramatic decrease occurred in Unit 8 (the

Table 1. Number of prairie falcon pairs by 10-km unit, 1990-1991.

| 10-km Unit | 1990 | 1991 | Change |
|---|---|---|---|
| 03 | 1 | 1 | 0 |
| 04 | 20 | 20 | 0 [a] |
| 05 | 41 | 48 | + [b] |
| 06 | 32 | 3 | – |
| 07 | 15 | 14 | – |
| 08 | 13 | 6 | – [a] |
| 09 | 5 | 6 | + |
| 10 | 2 | 3 | – [b] |
| 11 | 1 | 2 | + |
| 12 | 15 | 12 | – |
| 13 | 19 | 19 | 0 |
| 15 | 10 | 8 | – [a] |
| 16 | 1 | 1 | 0 [a] |
| 24 | 3 | 6 | + [b] |
| 25 | 2 | 1 | – |
| 26 | 3 | 3 | 0 |
| 37 | 2 | 2 | 0 |
| TOTAL | 185 | 183 | – |

[a] Number of pairs was lower in 1991 than in 1976-78.
[b] Number of pairs was higher in 1991 than in 1976-78.

Black Butte Area) where the number of pairs dropped from 13 in 1990 to 6 in 1991. The largest increase occurred in Unit 5 (the Swan Falls Area) where the number of pairs increased from 41 in 1990 to 48 in 1991. In 10 of the 10-km stretches, 1991 prairie falcon densities were within the range of densities recorded from 1976 to 1978. Three stretches (including Unit 5) had higher densities, and 4 (including Unit 8) had lower densities than any of the surveys in the 1970's (Table 1). An analysis of long-term trends for stretches surveyed between 1978 and 1990 suggested that 1991 prairie falcon populations were lower than the long-term average. Only 71 pairs were found in the 8 randomly-selected stretches that have been fully surveyed in 7 years (Table 2). The 1991 total was the second lowest density recorded for those stretches, and surveys in 1986 (the lowest year) may have underestimated the population (Kochert et al. 1986). In Units 7, 8, and 15 (the 3 stretches surveyed annually from 1976 through 1984 and every other year thereafter), 1991 prairie falcon densities were the lowest ever recorded (Fig. 3). Only 28 pairs nested in the 3 survey units in 1991; the previous low count had been 33 in 1982. Both of the long-term indexes were strongly influenced by the dramatic drop in falcon density in Unit 8 and may not reflect SRBOPA-wide trends.

The 30-km OTA shadow had 26 pairs compared to 99 pairs in the adjacent 30-km stretch to the west, and 33 pairs in the adjacent 30-km stretch to the east. However, the difference in densities is not as dramatic when viewed in relation to the area of available cliff in each 30-km stretch. The number of prairie falcon pairs per $m^2$ of cliff in the OTA shadow (0.035) was less than that west of the OTA (0.042) but higher than that east of the OTA (0.029).

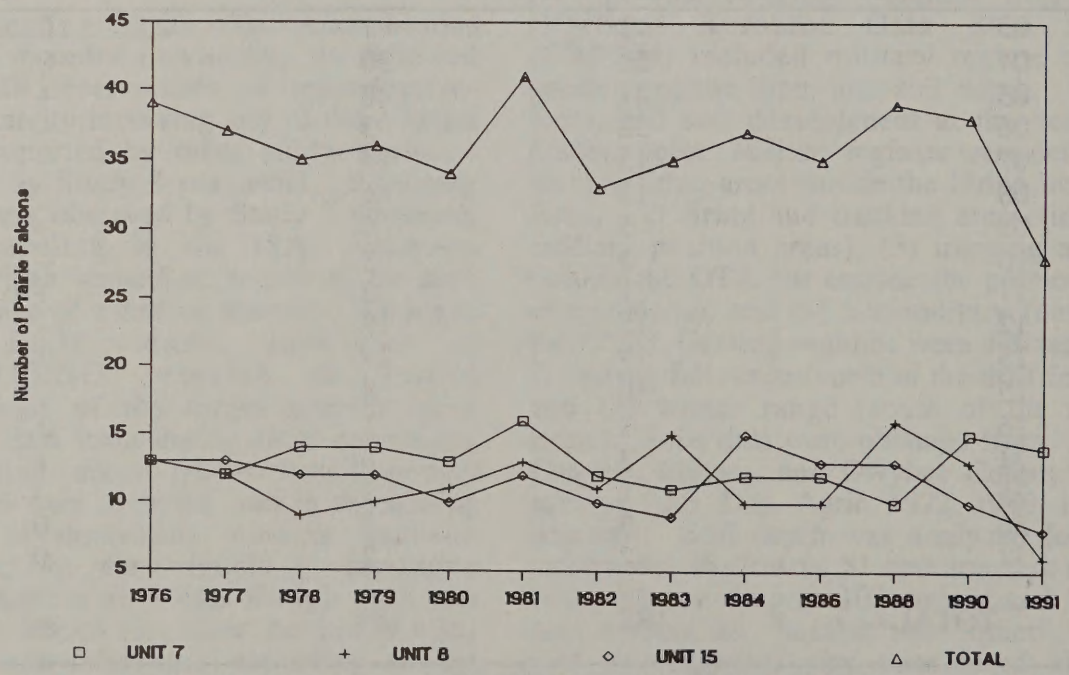


Fig.3. Number of occupied prairie falcon nesting areas in 10-km survey units 7, 8, and 15 in the SRBOPA.

Table 2. Number of occupied prairie falcon nesting areas in randomly selected 10-km units in the SRBOPA, 1976-78, 1986, 1988, 1990, and 1991.

| 10-Km Unit | 1976 | 1977 | 1978 | 1986 | 1988 | 1990 | 1991 | Mean |
|---|---|---|---|---|---|---|---|---|
| 3 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0.6 |
| 6 | 32 | 32 | 30 | 23[a] | 28 | 32 | 31 | 29.7 |
| 7 | 13 | 12 | 14 | 12 | 10 | 15 | 14 | 12.9 |
| 8 | 13 | 12 | 9 | 10 | 16 | 13 | 6 | 11.3 |
| 15 | 13 | 13 | 12 | 13 | 13 | 10 | 8 | 11.7 |
| 24 | 3 | 4 | 2 | 2 | 4 | 3 | 6 | 3.4 |
| 26 | 4 | 5 | 3 | 1 | 4 | 3 | 3 | 3.3 |
| 37 | 3 | 3 | 2 | 3 | 2 | 2 | 2 | 2.4 |
| | — | — | — | — | — | — | — | — |
| Total | 81 | 81 | 73 | 64 | 78 | 79 | 71 | 75.3 |

[a] Surveys of the south side of the river between the mouth of the Sinker Creek and Balls Line West may have been incomplete in 1986.

Evaluation of the Sampling Plan.--Of 94 nesting areas selected as controls and back-ups for Study 3's productivity studies, 34 were vacant, 4 were rejected because birds had been radioed at the site in 1990, and birds from 5 others were accidentally trapped by Study 2 in 1991. Of the remaining 51 nesting areas, 1 was not surveyed sufficiently to determine occupancy, and 8 were not surveyed sufficiently to determine success.

Prairie falcons were captured and radioed at 20 of the first 65 target nesting areas on Study 2's preselected list. Of the remaining target nesting areas, 25 were vacant, and 4 were rejected because adults had been radioed there in 1990. Trapping attempts were unsuccessful at 5 nesting areas, and trapping was not attempted at 11 occupied nesting areas on the preselected list for a variety of reasons (lack of road access, no birds seen early in the season, safety considerations, etc.). Eight falcons captured and radioed in 1991 were from non-target nesting areas: 5 were from nesting areas selected as controls; 2 were from low priority Study 2 nesting areas (Peregrine Chimney and Cattleguard Gate)--1 of which was also a 1990 radio site; and the eighth was caught at a nesting area (Wildhorse Butte NE) that had not been occupied before 1991 and was not on any preselected list. Success could not be determined at 2 of the nesting areas with radioed birds.

Reproduction.--Of 152 historical nesting areas selected by Studies 2 and 3 prior to the 1991 nesting season, 93 (61%) were occupied by prairie falcon nesting pairs. The OTA shadow had the lowest occupancy rate, with only 23 of 54 (43%) nesting areas occupied, and occupancy rates were highest west of the OTA where 52 of 71 (73%) historical nesting areas were occupied. East of the OTA, 18 of 27 nesting areas (67%) were occupied. Occupancy rates in the shadow were significantly lower ($G = 12.1$, $df = 1$, $P < 0.001$) than in the surrounding stretches.

Control pairs had a nesting success rate of 81%, the second best year on record (Table 3). Thirty-four pairs bred successfully, 1 breeding pair was unsuccessful, and breeding was not confirmed for 7 of the unsuccessful pairs. Successful control pairs fledged an average of 4.08 young, yielding an estimated 3.3 young fledged per pair, the highest productivity rate ever recorded in the SRBOPA when similar data sets were available for preselected pairs (Table 3). In 1991, we did not survey prairie falcon productivity east of the Bruneau Bridge (the eastern boundary of the ISA); however samples from 1974-77 and 1985-89 were also mainly from the western end of the SRBOPA.

Breeding attempts were confirmed during incubation at 16 of the 42 control nesting areas, and 15 of these pairs (94%) were successful; the highest success rate per attempt ever recorded in the SRBOPA (Table 3). Number of young fledged per attempt was 3.79, the same as the previously recorded high in 1985 and well above the 18-year average rate of 2.81 young fledged per attempt (Table 3).

Because the nesting success rate of control pairs (81%) did not differ significantly ($G = 0.6$, $df = 1$, $P = 0.55$) from that of pairs radioed in 1991 (73%), both groups were pooled in subsequent analyses of 1991 reproduction by region.

Nesting success rates in the OTA shadow (71%) were lower than those east and west of the shadow (80%), but differences were not statistically significant ($G = 0.71$, $df = 1$, $P = 0.50$). Success rates east of the shadow (81%, $n = 16$) were similar to those west of the shadow (80%, $n = 35$). Successful pairs in the OTA shadow fledged more young (mean = 4.46) than successful pairs east and west of the shadow (mean = 4.06), but the difference was not significant ($t = 1.14$, $df = 45$, $P > 0.15$).

Female fledging weights averaged 814 g (SD = 85) inside the shadow and 832 g (SD = 57) east and west of the shadow, and male weights averaged 583 g (SD = 59) inside the shadow and 562 g (SD = 38) outside the

Table 3. Nesting success and productivity of prairie falcons in the SRBOPA, 1974-1991. Sample sizes are in parentheses.

| Year | % of Pairs Successful | % of Attempts Successful | # Fledged/ Successful Attempt | # Fledged/ Attempt [a] | # Fledged/ Pair [b] |
|---|---|---|---|---|---|
| 1974 | 73% (15) | 64% (11) | 3.94 (17) | 2.52 | 2.88 |
| 1975 | 83% (23) | 86% (21) | 3.74 (27) | 3.21 | 3.10 |
| 1976 | 74% (23) | 79% (29) | 4.00 (41) | 3.16 | 2.96 |
| 1977 | 57% (14) | 67% (27) | 4.08 (25) | 2.73 | 2.33 |
| 1978 | 45% (20) | 18% (17) | 3.29 (17) | 0.59 | 1.48 |
| 1979 | 70% (40) | 75% (32) | 3.73 (30) | 2.80 | 2.61 |
| 1980 | 59% (49) | 65% (54) | 4.03 (36) | 2.62 | 2.38 |
| 1981 | 80% (51) | 83% (46) | 4.04 (22) | 3.35 | 3.23 |
| 1982 | 46% (26) | 69% (26) | 3.53 (17) | 2.44 | 1.62 |
| 1983 | 71% (31) | 73% (26) | 3.24 (17) | 2.36 | 2.30 |
| 1984 | --- --- | 88% (16) | 3.95 (19) | 3.48 | --- |
| 1985 | --- --- | 93% (14) | 4.08 (13) | 3.79 | --- |
| 1986 | --- --- | 44% (18) | 3.43 ( 7) | 1.51 | --- |
| 1987 | --- --- | 72% (36) | 4.32 (31) | 3.11 | --- |
| 1988 | --- --- | 78% ( 9) | 3.86 ( 7) | 3.01 | --- |
| 1989 | --- --- | 83% ( 6) | 3.67 ( 6) | 3.05 | --- |
| 1990 | --- --- | 74% (19) | 4.06 (18) | 3.00 | --- |
| 1991 | 81% (42) | 94% (16) | 4.08 (24) | 3.79 | 3.30 |
| Mean All Years | 67% (SD = 13%) | 72% (SD = 18%) | 3.84 (SD = 0.30) | 2.81 (SD = 0.78) | 2.56 (SD = 0.61) |

[a] Calculated as the product of % attempts successful and # fledged/successful attempt.

[b] Calculated as the product of % of pairs successful and # fledged/successful attempt. Data are not available for 1984-90 because prairie falcon pairs were not preselected in those years.

shadow. However, analysis of variance using brood size and length of seventh primary as covariates revealed no significant difference inside and outside the OTA shadow for either females ($F_{1,74} = 0.2$; $P > 0.5$) or males ($F_{1,70} = 1.1$; $P > 0.30$). Seventh primary length was significantly related to weight in both sexes, (F's = 17.6 and 7.3, P's < 0.01), but brood size had no significant effect (P's > 0.20).

Carry-over Effects of 1990 Radiotelemetry.--Seventeen of the 18 nesting areas where prairie falcons had been radioed in 1990 were again occupied by nesting prairie falcon pairs in 1991. Only the Sun Goddess nesting area was vacant. This occupancy rate is significantly higher ($G = 10.1$; df = 1; $P = 0.003$) than the rate for nesting areas randomly chosen for productivity and occupancy studies in 1991.

At least 9 and possibly 12 of the 22 birds radioed in 1990 were encountered in 1991 (Table 4). A female falcon radioed at the Mother Giant Dike nesting area in 1990 was found in a weakened state in April 1991 within 0.5 km of the 1990 Mother Giant Dike aerie. The bird was infested with air sac worms and subsequently died. Another female radioed in 1990 at Dedication Site was trapped as a breeding bird in the adjacent nesting area (Priest Rapids I). Four prairie falcons were trapped on the same nesting areas where they were trapped in 1990, and 3 were sighted on their same nesting areas (Table 4). At least 2 of these birds were still carrying their 1990 radios in 1991. Three other marked birds were seen in nesting areas where birds were radioed in 1990. Although alphanumeric codes could not be read on these birds, the colors and positions of the leg bands were the same as those of birds radioed at these locations. Observations confirmed that 3 nesting areas where falcons were radioed in 1990 were occupied by unbanded birds in 1991. At Tick II, a bird thought to be a male was sighted wearing a different color band than the male radioed in 1990. In all, at least 7 and possibly 9 of the nesting areas where birds were radioed in 1990 were occupied by at least 1 of the radioed birds in 1991. At least 4 nesting areas were occupied by new birds in 1991; 1 was vacant; and birds could not be identified at 4 others.

In 1991, nesting areas where falcons had been radioed in 1990 had higher nesting success rates (87%) than 1991 control pairs, but the difference was not significant ($G = 0.26$, df = 1, $P > 0.20$). Breeding attempts were successful at all 7 nesting areas where birds radioed in 1990 had returned in 1991. Both of the nesting areas with probable returns were successful.

**Golden Eagle Density and Reproduction**

Nesting Density.--In 1991, golden eagle pairs occupied 29 (76%) of the 38 preselected nesting areas in the SRBOPA. The number of occupied nesting areas was less than in 1990 and the preceding 3 years (Table 5). Eagle pairs occupied 19 (90%) of the 21 preselected nesting areas in the Comparison Area in 1991. Of the 11 vacant nesting areas in the SRBOPA and Comparison Area, 6 have not been occupied since 1982 or earlier. Of these, 3 (Bruneau Flats, Malad, and Simpkin) have not been occupied since 1978 or earlier. Two vacant nesting areas (Strike II and Swan Dam) were vacant for the third consecutive year, and eagles have used the nesting area associated with the PP&L 125 tower only once (in 1988). Two vacant nesting areas (Pump Station and Grand View Feedlot) were classified as occupied in 1990. However, observations by Study 2 in 1991 indicated that the pair from the "Beercase" nesting area regularly used the "Feedlot" territory so it appears that 1 pair has absorbed both nesting areas (and may have done so as early as 1989). A similar situation may have occurred at the Pump Station/Delates Delight nesting areas because only 1 of the 2 adjacent nesting areas has been occupied in each year since 1977.

Table 4. Status of prairie falcons radioed in 1990.

| Nesting Area | Band Number | Sex | 1991 Encounter | 1991 Nesting Area Status |
|---|---|---|---|---|
| Bruneau Flats | 1807-01213 | F | None | Occupied by 2 Unbanded Adults |
| Cattleguard Gate | 816-70247 | M | Trapped on Nesting Areas | Successful |
| Crane Falls I | 816-70248 | M | None | Occupied-Adults not Identified |
| Dedication Site | 1807-01206 | F | Trapped on Adjacent Nesting Area | Successful (Unmarked Pair) |
| Fawn Draw | 1807-01202 | F | Trapped on Nesting Area | Successful |
| Fever Basin Upstream | 1807-01204 | F | Trapped on Nesting Area | Successful |
| Guffey Fingers | 816-70243 | M | Confirmed Sighting on Nesting Area | Successful |
| Mother Giant Dike | 1807-01208 | F | Found Dying Near Nesting Area | Successful (Unmarked Pair) |
| Narrows | 1807-01207 | F | Confirmed on Nesting Area | Successful |
| | 816-70150 | M | Possible Sighting on Nesting Area | |
| Point | 816-70249 | M | None | Occupied-Adults Not Identified |
| | 1807-01209 | F | None | |
| Powerline | 1807-01203 | F | Trapped on Nesting Area | Successful |
| Rosie Upriver South | 816-70244 | M | None | 2 Unbanded Adults-Successful |
| Sand Rock | 1807-01201 | F | Possible Sighting on Nesting Area | Occupied Adults-Not Identified |
| Shoofly | 1807-01211 | F | None | Occupied-Adults Not Identified |
| Spoon Upstream | 816-70242 | M | Confirmed Sighting on Nesting Area | Successful |
| Strike Island | 816-70245 | M | None | Successful |
| | 1807-01212 | F | Possible Sighting on Nesting Area | |
| Sun Goddess | 816-70246 | M | None | Vacant |
| | 1807-01205 | F | None | |
| Tick II | 816-70156 | M | None [a] | Occupied-Adults Not Identified [a] |

[a] A male wearing a leg band was sighted at Tick II, but the color was different from that of 816-70156.

Table 5. Nesting success and productivity of golden eagles in the SRBOPA, 1971-1991. Sample sizes are in parentheses.

| Year | # Occupied Nesting Areas | % of Pairs Breeding | % of Attempts Successful | # Fledged/ Successful Attempt | # Fledged Per Pair | Total Fledged |
|---|---|---|---|---|---|---|
| 1971 | 34 | 100% (31) | 60% (20) | 1.89 (19) | 1.13 | 39 |
| 1972 | 34 | --- --- | --- --- | 1.64 (11) | --- | -- |
| 1973 | 35 | 65% (34) | 44% (18) | 1.37 ( 8) | 0.39 | 14 |
| 1974 | 35 | 73% (30) | 56% (18) | 1.42 (12) | 0.58 | 20 |
| 1975 | 33 | 75% (32) | 56% (18) | 1.43 (14) | 0.60 | 20 |
| 1976 | 35 | 70% (33) | 47% (15) | 1.62 (13) | 0.53 | 19 |
| 1977 | 34 | 82% (33) | 59% (17) | 1.53 (15) | 0.74 | 25 |
| 1978 | 32 | 80% (30) | 70% (10) | 1.71 (17) | 0.96 | 31 |
| 1979 | 30 | 97% (30) | 61% (23) | 1.53 (19) | 0.91 | 27 |
| 1980 | 31 | 87% (31) | 72% (18) | 1.77 (22) | 1.11 | 34 |
| 1981 | 30 | 100% (30) | 74% (23) | 1.73 (22) | 1.28 | 38 |
| 1982 | 30 | 87% (30) | 80% (25) | 1.95 (19) | 1.36 | 41 |
| 1983 | 28 | 96% (27) | 72% (18) | 1.56 (16) | 1.07 | 30 |
| 1984 | 31 | --- --- | 61% (18) | 1.55 (11) | 0.60 [a] | 19 |
| 1985 | 32 | 39% (31) | 42% (12) | 1.00 ( 4) | 0.16 | 5 |
| 1986 | 29 | 54% (28) | 29% (14) | 1.33 ( 6) | 0.21 | 6 |
| 1987 | 32 | 78% (32) | 32% (25) | 1.38 ( 8) | 0.34 | 11 |
| 1988 | 32 | 74% (31) | 55% (22) | 1.54 (13) | 0.63 | 20 |
| 1989 | 30 | 80% (30) | 63% (19) | 1.36 (14) | 0.69 | 21 |
| 1990 | 30 | 87% (30) | 80% (25) | 1.65 (20) | 1.15 | 33 |
| 1991 | 29 | 90% (29) | 73% (22) | 1.58 (19) | 1.03 | 30 |

[a] Based on % of pairs successful.

Reproduction.--Golden eagle reproduction in the SRBOPA was lower than in 1990, but higher than in the years 1984-1988 (Table 5). Percent of pairs breeding increased from 87% in 1990 to 90% in 1991, but percent of breeding attempts successful decreased from 80% to 73% between those years. The number of young fledged per successful nesting attempt decreased from 1.65 to 1.58, and number of young fledged per pair decreased from 1.15 to 1.03 between 1990 and 1991.

At least 5 eagle pairs (2 in the SRBOPA and 3 in the Comparison Area) produced 3 fledging-aged chicks in 1991. This is the first year since 1982 that we have observed any 3-chick broods in the SRBOPA. Although we have observed a 3-chick brood each year in the Comparison Area in recent years, we have not seen as many as 3 in any single year since 1980.

As in 7 of the previous 8 years, golden eagle reproduction in the SRBOPA was lower than in the Comparison Area, but differences in breeding and success rates were not significant (G-tests, df's = 1, P's > 0.10; Table 6). Percent of pairs breeding, percent of breeding attempts successful, and number of young fledged per successful attempt were all lower in the SRBOPA than in the Comparison Area (Table 6).

**Dispersal and Nest Site Fidelity**

Prairie Falcons.--In addition to the encounters with 9 (and possibly 12) prairie falcons radioed as adults in 1990 (Table 4), researchers observed marked adults in 7 other nesting areas in 1991. Three of the prairie falcons captured and radioed by Study 2 in 1991 had been marked as nestlings during the 1987 nesting season. These 3 birds were captured 1.7 km (Balls Pt Upstream Female), 4.6 km (Priest Rapids II Male), and 5.3 km (Hell Hole Gaging Station Male) from their natal areas. Another territorial prairie falcon radioed in 1991 (CSJ Male) had been marked as a nestling in 1990, 14.2 km from its recapture point.

Color-banded prairie falcons were observed as adults at the Ferry, Hell Hole Gaging Station, Tick II, and Tick III nesting areas during the 1991 nesting season. None of these birds could be individually identified because alphanumeric codes were not read. Three (Ferry, Hell Hole Gaging Station, and Tick III) wore blue bands on their left legs, indicating they had been marked as nestlings in 1987. The falcon observed at Hell Hole Gaging Station may have been the one recaptured and radioed in 1991, but this could not be confirmed. The bird seen at Tick II wore a black band on its left leg, indicating it had been marked as a nestling in 1990. We

Table 6. Nesting success and productivity of golden eagles in southwestern Idaho, 1991. Sample sizes are in parentheses.

| Study Area | % of Pairs Breeding | % of Attempts Successful | # Fledged/ Successful Attempt | #Fledged Per Pair |
|---|---|---|---|---|
| SRBOPA | 90% (29) | 77% (26) | 1.58 (19) | 1.09 |
| Comparison | 95% (19) | 88% (16) | 2.00 (13) | 1.67 |

also received a sighting of a falcon at Tick III wearing a black band, but it is not known which leg had the color band.

In February 1991, a private citizen found a dead banded prairie falcon (987-53081) that had been banded as a nestling in 1987. The bird was only 6.4 km from its natal aerie, and because it was very decayed, it is uncertain how long it had been dead.

Two prairie falcons banded as nestlings in 1991 were recovered approximately 1000 km from the study area. A nestling banded on 27 May at Jackass NW was found injured near Alliance, Nebraska on 6 July, 1098 km from its natal area. A nestling banded on 17 June at Tom Butte West was found dead near Brock, Saskatchewan on 12 August, 1096 km from its natal area.

Golden Eagles.--An adult golden eagle trapped by Study 2 at PP&L 119 had been marked as a nestling in 1976, 42.3 km from its breeding area. Study 3 personnel observed a wing-marked adult golden eagle at the Walters Butte nesting area. A wing-marked eagle (probably banded as a nestling in 1981) had also been observed there in 1988.

**Nesting of Raptors on the Benchland**

General Survey Results.--We located 64 occupied raptor nesting areas on benchlands in the ISA in 1991 (Table 7). Thirty were found within the OTA, and 34 were found outside the OTA. These included 8 ferruginous hawk, 8 northern harrier, 30 burrowing owl, and 18 short-eared owl pairs. Eleven of the 64 pairs were found at historical nesting areas, 15 were found during the random plot survey, and 38 were found incidentally by Study 3 personnel and other study teams. Although we checked all 64 historically occupied nesting areas in the ISA, only 19 were surveyed sufficiently to determine occupancy.

Seven of the 8 ferruginous hawk nesting areas had been historically occupied. One ferruginous hawk nesting area was found during the random plot survey. Of the 8 ferruginous hawk nesting areas found, 4 were on PP&L transmission line towers, 2 were on artificial platforms, and 2 were on rock outcrops.

No nesting pairs were found at historically occupied northern harrier and short-eared owl nesting areas. Four burrowing owl nesting areas had been occupied historically. Six of 8 occupied northern harrier nesting areas, 22 of 31 burrowing owl nesting areas, and 10 of 18 short-eared owl nesting areas were found incidentally. All northern harrier and short-eared owl nests were on the ground. All burrowing owl nests except 1 were in ground-level burrows. However, 1 burrow in the Impact Area was excavated in the side of an artificial berm supporting a moving target system.

Relative Abundance.--Of 200 random plots established for assessment of ground-nesting raptor abundance, 192 were surveyed 4 times as planned (a total of 768 surveys). Fifty-five random plots were surveyed inside the OTA compared to 137 plots outside the OTA. Fifteen occupied nesting areas were located during searches at the random plots (Table 8). Six nesting areas were found inside the OTA; 9 were found outside the OTA. Short-eared owls were the most abundant species overall, accounting for 8 of the 15 nesting areas found. Five of the 8 short-eared owl nesting areas and all burrowing owl nesting areas were found outside the OTA. All ferruginous hawk and northern harrier nesting areas were located inside the OTA. We found 0.11 nesting areas per random plot inside the OTA compared to 0.06 nesting areas per plot outside the OTA; however, contingency table analysis suggested that frequencies of occupied nests in the 2 areas did not differ significantly ($G = 1.93$, $df = 1$, $P = 0.20$).

Results of the random plot survey indicate that benchland-nesting raptors are not abundant in the ISA. However, the 15 nesting areas found represent only 23% of

Table 7. Number of occupied raptor nesting areas found on the ISA benchlands in 1991. Numbers in parentheses indicate percent of nesting areas found by each survey method.

| Survey Type | Ferruginous Hawk | Northern Harrier | Burrowing Owl | Short-Eared Owl | Totals |
|---|---|---|---|---|---|
| Historical | 7 (88) | 0 ( 0) | 4 (13) | 0 ( 0) | 11 (17) |
| Random Plot | 1 (12) | 2 (25) | 4 (13) | 8 (44) | 15 (23) |
| Incidental | 0 ( 0) | 6 (75) | 22 (74) | 10 (56) | 38 (59) |
| Totals | 8 | 8 | 30 | 18 | 64 |

the 64 nesting areas found during the overall effort (Table 7). Thirty-eight (59%) of the 64 nesting areas were found incidentally, e.g., by other study teams or by Study 3 personnel during other survey efforts (Table 7). Three (1 northern harrier and 2 burrowing owl) nesting areas were found incidentally within random plots but were missed during circular-plot and transect surveys.

The relatively low number of nesting areas detected during the random plot survey and the number found in the overall effort (15 compared to 64 nesting areas) should be an important consideration in planning future raptor nesting surveys on the ISA's benchlands. The 1991 sampling effort required a sizeable investment of labor and associated costs. Future surveys might focus more effort in areas where nests are likely to occur, by widening searches around historical nest locations and searching other areas where suitable habitats are known to occur.

Effectiveness of Transect and Circular-Plot Methods.--Of 768 survey bouts conducted at random plots, 387 consisted of transects and 381 consisted of circular plots. Of 15 occupied nesting areas found, 12 were detected only once during 4 surveys, and 3 were detected twice, for a total of 18 detections (Table 9). Of the 3 nesting areas with 2 detections, 2 were found during transect surveys only, and 1 was found during a transect and circular-plot survey. Ten of the 18 detections occurred during the last 2 surveys, between 24 April and 24 July.

Of 18 detections of occupied nesting areas, 5 occurred during circular-plot surveys, and 13 occurred during transect surveys (0.013 detections per circular plot compared to 0.034 detections per transect, Table 10). Ten of 15 nesting areas were found only by transect surveys, and 4 were found only by circular-plot surveys. This suggests that transect surveys may be more effective than circular-plot surveys in detecting nesting raptors on the bench; however, a sign test indicated that detection rates of the 2 methods did not differ significantly ($P = 0.09$).

Although the number of occupied nesting areas found during transect surveys was higher than during circular-plot surveys, the investment of time for transect surveys was higher than for circular-plot surveys. Each circular plot was surveyed for 30 min compared to a mean survey period of 53 min for transect surveys. A total of 190.5 hr was expended during 381 circular-plot surveys compared to 342.4 hr during 387 transect surveys, with a return for circular-

Table 8. Number of occupied raptor nesting areas found on ISA benchlands during random plot surveys. Numbers in parentheses indicate the number of occupied nesting areas found per random plot.

| Species | Inside OTA (n = 55) | Outside OTA (n = 137) | Totals (n = 192) |
|---|---|---|---|
| Ferruginous Hawk | 1 | 0 | 1 |
| Northern Harrier | 2 | 0 | 2 |
| Burrowing Owl | 0 | 4 | 4 |
| Short-eared Owl | 3 | 5 | 8 |
| Total | 6 (0.06) | 9 (0.11) | 15 |

Table 9. Detections of individual nesting areas by circular plot and transect methods during the random plot survey.

| Nesting Area | Species | Detected During Circular Plot Survey [a] | Detected During Transect Survey [a] |
|---|---|---|---|
| ISA Point 100 N | Burrowing Owl | 1 | 0 |
| " 100 S | " | 0 | 1 |
| " 100 | Short-eared Owl | 1 | 0 |
| " 113 | " | 0 | 1,1 |
| " 146 | " | 0 | 1 |
| " 149 | Burrowing Owl | 0 | 1 |
| " 288 | Northern Harrier | 1 | 0 |
| " 307 | Burrowing Owl | 0 | 1,1 |
| " 792 | Short-eared Owl | 0 | 1 |
| OTA Point 35 | Northern Harrier | 0 | 1 |
| " 79 | Ferruginous Hawk | 1 | 1 |
| " 113 | Northern Harrier | 0 | 1 |
| " 172 | Short-eared Owl | 0 | 1 |
| " 195 | " | 1 | 0 |
| " 222 | " | 0 | 1 |
| Total Number of Detections | | 5 | 13 |

[a] 0 = No; 1 = Yes. If "1" is entered more than once, the site was detected independently during more than 1 survey.

Table 10. Comparison of transect and circular plot methods for surveying benchland raptors.[a]

| Survey Method | # Detections of Occ. Nesting Areas | #Detections/ Visit | Detections/Hour of Effort |
|---|---|---|---|
| Circular Plot | 5 | 0.013 | 0.026 |
| Transect | 13 | 0.034 | 0.038 |

[a] For circular plot surveys n=381; for transect surveys n=387.

plot surveys of 0.026 detections per hr compared to 0.038 detections per hr for transect surveys.

Nesting Success.--At least 2 of the 64 occupied nesting areas on ISA benchlands were occupied by nonbreeding pairs. Breeding was confirmed at 36 of the remaining 62 nesting areas, but only 7 of these were found during incubation. Nesting success was determined at 31 nesting areas, and complete fledge counts were obtained at 4 of 29 nesting areas known to be successful. Because only 7 nesting areas were found during incubation and nesting success was determined at only 4 of these, we did not assess percent of breeding attempts successful or number of young produced per attempt. Of 31 nesting areas with known success, 5 were confirmed at random plots, 7 were confirmed at historical nesting areas, and 19 were confirmed at incidental nesting areas.

Habitat Assessments.--Logistic regression models failed to predict occupancy by individual raptor species, using variables obtained by Study 3 and the DRDBM ($P$'s > 0.20). We suspect that this result may be related to low sample sizes because the regression model for all species pooled was significant (likelihood ratio = 74; $P = 0.01$). Number of rock outcrops and artificial structures within a 50-m radius were both significant coefficients in the model for all species pooled. Both rock outcrops and artificial structures were recorded significantly more often around ferruginous hawk nests than around random points ($G = 5.98$, df = 1, $P = 0.02$; $G = 15.81$, df = 1, $P = 0.0001$). All ferruginous hawk nesting areas had either a rock outcrop or an artificial structure within a 50-m radius of the nest.

Canonical discriminant analysis involving 6 variables collected by Study 5 revealed a significant difference between occupied and unoccupied plots ($F_{6,108} = 4.02$, $P < 0.01$). Factors that correlated positively with the canonical discriminant axis were badger burrow densities and the intensity of military vehicle tracking (both the presence of tank tracks on transect segments and the coverage of tank tracks as estimated from point frames). Both tank tracks and badger burrows were more abundant at plots where raptor nesting areas were found (Table 11). Variables not important in discriminating the 2 groups were shrub cover, total vegetative cover, and ground squirrel burrow densities.

Analyses of randomly selected points indicated that the frequency of hills in the OTA was similar to points outside the OTA ($G = 0.001$, df = 1, $P < 0.001$). The frequency of shallow, medium, and deep soils was similar at OTA and non-OTA points ($G = 1.22$, df = 2, $P > 0.20$). However, significantly more OTA points had rock outcrops in a 50-m radius ($G = 9.17$, df = 1, $P$

Table 11. Mean values of habitat characteristics at randomly-selected plots.

| | Raptor Nesting Area Present | | No Raptor Nesting Areas Found |
|---|---|---|---|
| Tank Track Cover | 2.77% | * | 0.42% |
| Tank Tracks (Presence on Segments) | 2 | * | 1 |
| Badger Burrows | 77 | * | 36 |
| TGS Burrows | 114 | NS | 75 |
| Shrub Cover | 7.53% | NS | 9.02% |
| Vegetation Cover | 43.93% | NS | 42.57% |

*Significantly correlated with the canonical discriminant axis.

= 0.004). No artificial structures were recorded within 50 m of randomly-selected points in the OTA, but artificial structures were also rare outside of the OTA (< 4% of points). Although a higher proportion of OTA points were north of the drift fence (71% vs. 60%), the difference was not significant ($\underline{G} = 2.38$, df = 1, $\underline{P} = 0.14$).

We found no evidence that raptors nesting within the OTA avoided centers of military activity. We found raptors nesting in all OTA sectors except 3 (B3, D2, and C3). The frequency of raptor nesting pairs in sectors did not differ from the frequency of random points in sectors ($\underline{G} = 7.80$, df = 10, $\underline{P} = 0.65$). Nor did the distribution of nesting pairs by sector differ from what would be expected based on the area of each sector ($\underline{G} = 8.65$, df = 9, $\underline{P} = 0.71$). Nests and random points occurred at similar distances from firing points (mean = 4.8 km for both groups; $\underline{t} = 0.04$, df = 83, $\underline{P} = 0.97$). A slightly higher proportion of nests occurred within the Impact Area, within 1 km of firing fans, and within 1 km of the Multi-purpose Range Complex, but differences in distribution of nests and random points were not significant ($\underline{G} = 0.119$, df = 1, $\underline{P} = 0.67$; $\underline{G} = 0.98$, df = 1, $\underline{P} = 0.37$; $\underline{G} = 0.19$, df = 1, $\underline{P} = 0.69$).

## PLANS FOR NEXT YEAR

In 1992, we will continue prairie falcon and golden eagle density and productivity surveys throughout the SRBOPA. However, we will not study carry-over effects of radio transmitters on prairie falcons, nor will we continue the nesting area fidelity work. As in 1991, we will survey the ISA for benchland raptors but will focus less on assessing relative abundance inside and outside the OTA and more on obtaining data on nesting success. We will use a quadrat survey approach similar to that used in 1990, but the sampling units will be larger (9 $km^2$ as opposed to 4 $km^2$).

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# Influence of Military Training on the Behavior of Raptors in the Snake River Birds of Prey Area, 1991

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*Annual Summary*

*Prairie falcons (Falco mexicanus) did not appear to suffer adverse effects from wearing 13-g backpack radio transmitters; instrumented birds preened around their packages immediately after release, but quickly resumed courtship and later tended and fed their nestlings at rates similar to rates exhibited by birds without transmitters. Radio-tagged birds reared nestlings similar in weight and number to those reared by non-instrumented birds. Prairie falcons exhibited bimodal activity patterns, reduced their activity during cold and windy periods, and roamed widely across the study area making extensive use of the Orchard Training Area (OTA). Falcons ranged up to 32,250 m from their nests and used an average home range of 21,387.7 ha (determined using the 95% core area around the harmonic mean). Home range overlap was extensive among all pairs and often complete between neighboring pairs. Falcons nesting in the OTA shadow ranged significantly farther from their nests, and tended to exploit a wider variety of prey items and spend less time in their territories than those nesting west of the OTA shadow. However, these differences did not result in lower rates of prey delivered to nestlings or in lower productivity. Raptor use of the OTA was less during periods of firing but not during periods of tank maneuvering without firing, or when convoys travelled the Range Road. The behavior of raptors remaining on firing ranges during firing changed little compared to behavior on ranges when firing did not occur.*

## OBJECTIVES

1. Assess the impacts of backpack radio transmitters on the behavior and productivity of prairie falcons.
2. Determine the spatial use patterns of prairie falcons in the OTA shadow and west of the shadow.
3. Assess the impacts of military training on the ranging habits, nesting behavior, and productivity of prairie falcons.
4. Assess the impacts of military training on the abundance and behavior of raptors utilizing firing ranges in the OTA.

5. Monitor habitat use of resident, adult golden eagles (*Aquila chrysaetos*).

## INTRODUCTION

The Idaho National Guard's OTA occupies approximately 1/3 of the Snake River Birds of Prey Area (SRBOPA). Concern about the possible impacts of training armored cavalry troops prompted the development of a long-term, 5-team study to assess the use of the OTA by raptors and to determine if military training influences the behavior and/or productivity of these birds and their prey.

Our study (Study 2) is concerned primarily with understanding if and how military training affects raptor behavior. To fully understand the influence of any disturbance on wildlife, we must also explore how it affects fitness components (fecundity and survivorship) of individuals and the viability of populations. We therefore offer some insight into how changes in behavior are (or are not) translated into effects on the fecundity of individuals. This link and the connection between individual productivity and population viability is being investigated further by Study 3.

Understanding behavioral changes in response to human activity is an important step in assessing human impacts. Behavioral responses are a species' first reaction to natural and anthropogenic change. Therefore, documentation of changes in behavior can serve as an early indicator of human impact. Moreover, if an animal's behavioral adjustment to disturbance can be tied to specific human actions, we can suggest how human behavior can be modified to reduce our disturbance to wildlife. Observations of behavioral changes in response to human activity alone are insufficient for concluding that humans are (or are not) adversely affecting wildlife; behavioral changes must be tied to potential or real impacts on components of fitness before such conclusions are warranted.

This report is a preliminary summary of data collected during 1 season. In assessments of impact on populations inhabiting variable environments such as the Great Basin Desert, we must not rely on results from 1 year. This season was characterized by abundant Townsend's ground squirrels (*Spermophilus townsendii*; Knick, this volume), and a cool, wet spring (April and May averaged 0.17 C and 1.4 C cooler and received 1.14 cm and 0.91 cm more rainfall than normal; National Weather Service, Boise, ID); therefore, we view this year's results as a best-case scenario of the influence of military training on raptors. In future years, when prey resources decline or weather patterns change, our results likely will be different. Continued research and larger samples should provide more conclusive tests of our hypotheses.

## METHODS

### Terminology

We use a variety of terms when we refer to the space used by prairie falcons in the Snake River Canyon. A nesting area is a stretch of cliff where nests are found year after year, but where no more than 1 pair has ever bred at 1 time. A territory is defined as the cliff and canyon terrain actively defended by a pair during a given year. An aerie, or a scrape, refers to the actual nest location.

### Trapping Prairie Falcons

Sixty-eight historical nesting areas were investigated for the possibility of trapping prairie falcons in 1991 (29 were from the Study 2 OTA pre-selected list, 4 were from the Study 3 OTA pre-selected list, and 35 were from the Study 2 west of OTA list). We rejected 40 of them because adults were

not present or not exhibiting territorial behavior, sites were heavily disturbed by human recreational activities, other raptors were nesting in proximity, or trap placement sites were unavailable. We set traps during courtship, egg-laying, incubation, and brooding in 31 areas and captured a total of 34 adult prairie falcons from 28 known nesting areas during March, April, and May 1991 (1 individual was captured twice).

Nesting areas selected for trapping were a random sample of all areas previously stratified into 2 categories: those within the OTA shadow (areas within the 30 km of the Snake River Canyon immediately south of the OTA; BLM units 7, 8, and 9) and those west of the OTA shadow (areas northwest of BLM units 7, 8, and 9). Twenty-three of our captures occurred west of the OTA, and 11 occurred in the OTA shadow. We placed a radio transmitter on each captured falcon unless we believed that the bird was not a resident of the territory where we were trapping. We placed radio transmitters on 9 birds in the OTA shadow and 19 birds west of the OTA shadow.

Two 2-person teams trapped from 8 March through 6 May 1991. They observed each nesting area until a falcon exhibited signs of territory occupancy (perching, courting, copulating, or defending the area), and then placed traps within (or as close as possible to) the territory. To avoid trap placements dangerous to personnel and possibly disruptive to falcons (Clugston 1990), we captured falcons away from the aerie using noose harnesses or dho-gazas (Bloom 1987). We lured falcons to the traps with rock doves (*Columba livia*), European starlings (*Sturnus vulgaris*), house sparrows (*Passer domesticus* ), or great-horned owls (*Bubo virginianus*). Dho-gazas (our most successful trap; 14 captures using live prey as bait, 18 captures using owls) were situated either singly or 2 were used in an L-shape. Nets used when luring with live bait were constructed of 10.2-cm (4-inch), hand-tied nylon mesh that was dyed dark brown. They measured 0.92 m (3 ft) tall by 1.5 m (5 ft) wide and were attached in a break-away system to steel poles (1.5 m [5 ft] tall, 1.3 cm [0.5 in] diameter) driven into the ground. Each net was weighted with a 113.6-g (4-oz) sinker tied to a 6.1-m (20-ft) long drag line. We fitted live prey with jesses and attached them to stakes located in the central portion of the net area.

Trapping with live bait worked well until mid-April; bait was obvious only to specific falcons and seldom attracted non-target birds. However, as falcons began laying and incubating eggs, their response to live prey diminished, and we attracted them to nets with great-horned owls. Dho-gazas were modified by using 2 nets each measuring 1.2 m (4 ft) tall by 1.8 m (6 ft) wide attached to steel poles (2.4 m [8 ft] tall, 1.1 cm [3/8 in] diameter) and placed in an L-shape. Both nets were placed as high as possible on the poles. We weighted each net with 2 113.6-g (4-oz) sinkers tied to 6.1-m (20-ft) long braided nylon line. We clipped 1 of these drag lines to each net, and clipped the second toward the weight end of the first line. A great-horned owl was tied (using jesses, a swivel and leash) to a stake positioned in the ground in the central area of the nets. We used topographical features as a backdrop to camouflage nets, but maintained open access for stooping falcons.

When an individual was captured, it was restrained immediately and hooded (Bloom 1987). Each unbanded falcon was marked with a USFWS aluminum band on the left leg and a black alpha-numeric band on the right leg. We collected the following information on each bird: weight (g; using a Pesola scale), wing chord (mm), wing span (mm; twice the distance from the middle of the back to the longest primary while the wing was fully extended), wing width (mm; at the widest portion of the wing), body circumference (mm; at the widest point over the sternum and under the wings), molt

(absence of feathers and/or presence and percentage of regrowth), and a general description of the bird's condition (including any observations of injuries, presence of brood patches, a subjective scoring of the "keel" [slope of the pectoralis from the sternum] and subcutaneous fat). Crop content (percentage full in 25% categories) was also recorded. Sex was estimated based on size and behavior observed after capture.

We applied 12-13-g radio transmitter backpack packages (transmitter, Teflon straps and leather sternum patch). The general configuration of the harness follows Buehler et al. (in press), with the modification of a leather sternum patch added in an attempt to distribute the pull of the backpack evenly across the crest of the sternum. We fitted the harness loosely, allowing approximately 20 mm between the bird's back and the transmitter. Because the first 2 instrumented falcons removed their backpacks after less than 2 days, we switched from securing the harness with all-cotton thread to using dental floss on the posterior connections and cotton thread on the anterior connections (to allow the package to be shed eventually). In addition, we put all knots on the underside of the Teflon to reduce the chance that the falcon would pick them loose. DRITZ "Fray-check" was used to prevent fraying of the Teflon ribbon. Birds were released as soon as the attachment was completed.

We monitored each falcon for at least 1 hr after release to determine if the transmitter package and/or handling adversely affected the bird's flight or behavior. Each bird was monitored again for 2 hr (in most cases on the next day) to determine whether the transmitter was still on and whether the bird's behavior appeared normal.

Two birds that were radio-tagged in 1990 did not shed their transmitters. We attempted to re-capture them after their young had fledged and successfully re-captured 1. We removed the radio and observed little sign of feather wear or skin irritation. We were not able to catch the other bird, but its mate was captured and banded.

Band combinations and physical characteristics of all falcons captured in 1991 are listed in Appendix A.

**Productivity**

Field protocol.--We monitored the breeding status of the 27 pairs of prairie falcons that included a radio-tagged individual (the male at Priest Rapids II shed its transmitter 1 day after capture and was not monitored or included in productivity analyses). Young were viewed at a distance of 100-1000 m with Kowa or Questar spotting scopes at least twice to determine age (estimated according to Moritsch [1983]). When at least 1 nestling was estimated to be at least 30 days old, we rappelled to aeries to count and measure nestlings, as counts of 30-day old nestlings are acceptable estimates of fledging success (Steenhof 1987). At 4 aeries (Cattleguard Gate, Balls Basin Hamer, Mother Giant Upstream, and Fawn Humpback) we were unable to see and/or remove all of the nestlings because some had already fledged or because the nesting cavity was extremely deep. We (and Bureau of Land Management [BLM] personnel) viewed these nests repeatedly from the ground to get a complete nestling count (a complete count was obtained at each site except for Mother Giant Upstream). Likewise, we did not determine chick age at 1 site (Fever Basin) before fledging and therefore we only counted those fledglings from the ground. One brood was partially preyed upon (Wildhorse Southwest) making it impossible to get a complete count of nestlings. All aeries that we suspected to be unsuccessful were visited a minimum of 3 times throughout the breeding season to verify that no fledged young were present. Suspected aerie

locations at failed sites were rappelled for evaluating the cause and timing of failure.

We made the following measurements on nestlings: weight (g; using a Pesola scale), span of right footpad and length of right seventh primary (mm; using a transparent ruler), and width of right tarsus (mm; from front to back immediately above the metatarsus using dial calipers). Nestlings were placed unrestrained in a cloth bag for weighing. Footpad was measured from the distal end of the pad on the hind toe (hallux) to the distal end of the pad on the middle (third) toe with toes maximally extended. Seventh primary length was measured on the distal side, by inserting the ruler between the seventh and eighth primaries. In addition, we felt the crop to estimate its fullness (percentage full) and noted the general health of each nestling. Three nestlings were not measured completely (2 were not banded) because these healthy nestlings appeared unusually stressed by handling. To minimize inter-individual differences in measuring technique, only 4 Greenfalk Consultants (GFC) and 4 Bureau of Land Management (BLM) personnel measured young. They were trained simultaneously at the start of the season. Moreover, to reduce biases we used mixed GFC and BLM teams on approximately 35% of the climbs.

All but 2 nestlings measured were banded on the right leg with a U.S.F.W.S. band and banded on the left leg with a black anodized, alpha-numeric band. Each of 6 nestlings from 3 nests was also outfitted with a tarsal-mounted radio transmitter. Transmitters weighed 6 g and were attached with leather strips sewn together with cotton thread.

Analyses.--We tested the null hypothesis that radio transmitters had no effect on nesting falcons by comparing productivity at our study (experimental) nesting areas to the productivity at nesting areas tended by non-instrumented (control) birds. These control nesting areas were monitored by BLM personnel. We used a 1-way ANOVA with brood size and length of seventh primary as covariates to assess differences in nestling weight between control and experimental sites. Crop weight was estimated from crop fullness in previous feeding trials (BLM, unpubl. data), and these weights were subtracted from nestling weight before this analysis. We used likelihood ratio G-tests to compare the number of pairs successfully fledging young to those failing to produce fledglings at control and experimental sites. We did not use territories with data insufficient to assign fate in this analysis. We used t-tests to compare the average number of young fledged per pair and per successful attempt between control and experimental sites. Lastly, we compared prey delivery rates and nest attendance of males and females wearing transmitters with the rates and nest attendance of individuals that were not radio-tagged, but that were mated to radio-tagged falcons.

We tested the null hypothesis that military training did not influence productivity by correlating productivity with the extent to which instrumented falcons utilized the OTA. Use of the OTA was measured by quantifying the percentage of telemetry fixes of each falcon within: (1) the OTA boundaries and (2) the impact area (inside the Range Road).

**Radio Telemetry**

Field protocol.--We divided the study area into 7 zones ranging in size from 50-80 $km^2$. These zones were small enough to allow detection of most birds using the area. Each zone included 4-6 permanent receiver sites located on prominent buttes, ridges, and outcroppings (Fig. 1). Receiver site locations were surveyed using a combination of Global Positioning System (GPS), Position Azimuth Determining Systems (PADS), and topographical maps. Receiver

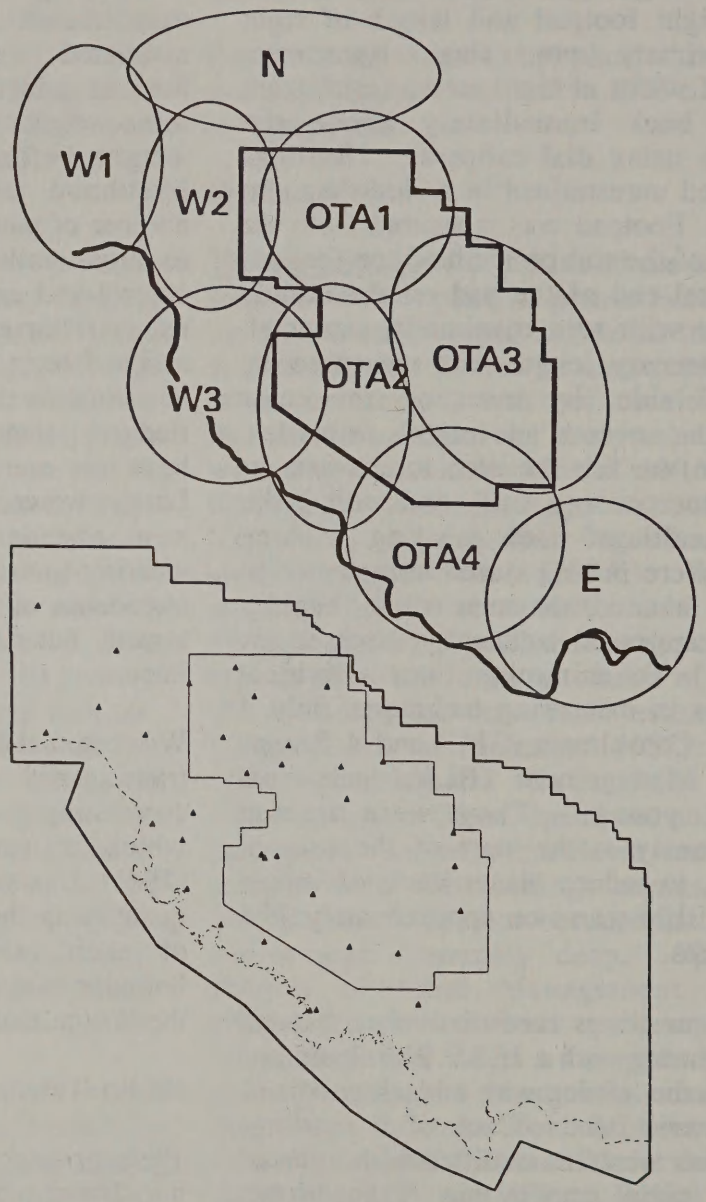



Fig. 1. Zones used for radio tracking (upper map) and locations of receiver sites (lower map; sites marked with small triangles). The OTA boundary is shown on both maps for orientation (thin, solid line). The lower map also includes the Integrated Study Area boundary (thick, solid line) and the north rim of the Snake River Canyon (dotted line).

sites were positioned throughout the zone to allow simultaneous bearings taken on birds in the zone from 3 or more sites to cross at approximately right angles, thereby minimizing triangulation error (White and Garrott 1990). We varied our use of receiver sites until 15 June, when we determined the best 4 sites within each zone. Thereafter, all monitoring sessions for a given zone used the same 4 receiver sites.

Radio-tracking team members were trained from 1-15 April. Each member became familiar with the equipment, receiver sites, and protocol by estimating the location of stationary beacons and instrumented falcons before intensive radio-tracking commenced.

A team of 4 radio-trackers was deployed to each zone 16 times (8 AM sessions beginning 30 min before sunrise and continuing until 1330, and 8 PM sessions beginning at 1330 and lasting until approximately sunset) from 17 April to 13 July 1991. We randomly selected the order for sampling zones, with the constraint that each zone had to be sampled once in the morning and once in the evening every 14 working days (this was occasionally interrupted so that we could use 1 receiver site located in the impact area and only accessible on days when no firing occurred on the ranges). Tracking sessions were conducted under all weather conditions unless lightning and/or heavy rain threatened personnel and/or receiving equipment.

Each member of a tracking team was positioned at 1 of the receiver sites within the zone. They used 4-element, hand-held Yagi antennas and programmable scanning ATS receivers to sequentially sample for radio frequencies of instrumented falcons. When a tracker detected a signal, he/she used a hand-held 2-way radio to alert the team coordinator to the bird's presence. The coordinator maintained radio contact with each team member and focused the team's efforts on a specific bird. When at least 3 trackers were receiving a bird's signal, the coordinator called for a simultaneous bearing and each tracker took a bearing from their location to the signal. The coordinator entered each bearing into a laptop computer programmed to determine the error associated with a given triangulation attempt and to spot systematic errors resulting from misaligned compasses, electrical interference, etc. Triangulation attempts were repeated on each bird until either an error ellipse of < 1000 ha was obtained, the bird was deemed out of range, or the bird's signal was lost by more than 1 tracker. The majority (77.5%) of fixes with errors < 1000 ha were obtained when all 4 trackers were able to simultaneously take bearings. We allowed at least 30 min between successive fixes of < 1000 ha on the same bird. Thirty min is sufficient time for a falcon to easily traverse the study area and taking bearings at this interval distributes our fixes throughout the study period, thereby assuring that our sample represents the falcons' use of the study area (White and Garrott 1990).

We continued to monitor falcon use of the study area until all birds dispersed. A full tracking team sampled zones once per day from 15-28 July (alternating between AM and PM shifts, and OTA and outside OTA zones). Most birds had left the study area by 28 July so we sent teams of 2-4 trackers to zone W2 (the zone with the most falcon activity) from 29 July - 4 August to quantify the gradual reduction in use of the area by the remaining birds. These trackers scanned for birds from 0600-1000 hr each morning and then drove in search of falcons to determine if radios had been shed and/or to obtain visual observations of the few remaining birds.

We supplemented our ground-based tracking efforts with 7 aerial searches of the study area from 6 July to 7 August. We flew a Cessna 180 or 210 outfitted with 2 side-facing, 4-element Yagi antennas for 3-4 hr

each trip. We surveyed the study area by flying 2-3 transects parallel to the Snake River Canyon (at least 1 transect was on each side of the river) and then searched for dispersing falcons in the surrounding Owyhee and Boise mountains. We concentrated our search efforts in areas where dispersing falcons have been previously documented (Dunstan et al. 1978). We regularly flew over the Boise foothills from Glenns Ferry to Smith Prairie, to Idaho City, to Garden Valley and up to 25 km north of Emmett. We took 1 extended trip east past Sun Valley to Copper Basin (a suspected dispersal area). Our regular route in the Owyhee mountains went as far south as the Sheep Creek 3 Military Operations Area (MOA) then north and east past Silver City to Reynolds. We recorded whether radio-marked falcons were present and their approximate location in the study area with Loran-C. Flights were conducted in the morning at altitudes of 600-1500 m above ground level.

We returned to 3 nesting areas from 10 to 25 July to monitor the dispersal of radio-tagged nestlings. Two observers walked into the territory and tracked nestlings to make visual contact. The presence or absence of tagged nestlings, their health, activity, and the condition of the radio was recorded.

Analyses.--We used Lenth's (1981) maximum likelihood estimator to determine an error ellipse around each triangulation estimate. This estimator was selected because it allowed us to refine our error estimates by including the known variation in bearing error associated with our telemetry system. We used a program developed by Brett Hoover (H & H Consulting, Bradford, PA) that calculated estimated animal locations and the associated error ellipses. We re-examined Clugston's (1990) data and determined that the standard deviation in mean angular error for our telemetry system was 6.5 (error = -1.6 , $n$ = 608), not 2.2 as previously reported (Clugston 1990). We calculated this standard deviation after excluding the most extreme 10% of the errors (this removed errors likely resulting from signal bounce).

We used 2 criteria for selecting acceptable fixes of falcon locations, 1 adequate for characterizing ranging behavior and 1 to characterize habitat use. First, we decided that any fix with an error ellipse < 1000 ha was adequate to obtain a point estimate for range and movement analyses. Although the error associated with these point estimates is large, it is small enough to detect changes in a bird's location that are approximately 3 km or greater and therefore sufficient to characterize its general movement pattern. These location estimates were entered into Kenward's (1990) RANGES IV program to calculate home range size and characterize its shape, to determine overlap among home ranges, and to compute average and maximum travel distances from aeries and other centers of activity. Home ranges were estimated with harmonic mean methods (Dixon and Chapman 1980) and peeled polygons centered at the aerie (Kenward 1987). We used a 40 x 40 grid and positioned fixes in the center of grid squares before calculating the harmonic mean isoclines to reduce plotting error (Spencer and Barrett 1984).

Second, we selected all fixes with an error ellipse < 200 ha. These ellipses are small enough to allow meaningful characterization of habitat use (Nams 1989). We will obtain estimates of vegetation within these ellipses from the BLM Geographical Information Systems (GIS) basemap of the study area when the map is complete.

We obtained a measure of the general activity of prairie falcons in the study area by recording the number of birds contacted and the number of contacts resulting in fixes with error ellipses < 1000 ha each hr from 6

prominent receiver sites (3 in the OTA and 3 outside the OTA). Using 1 observer's record of weather, we correlated these contact rates through the season with estimated wind speed, temperature, estimated cloud cover and type, and rainfall. We compared contact rates at the 3 sites in the OTA to contact rates at the 3 sites outside of the OTA using a 1-way repeated measures ANOVA. Analyses were done separately for 2 response variables (the average number of birds contacted per hr and the average number of good fixes [error ellipse < 1000 ha] per hr). The analysis had 1 between subjects factor (OTA versus outside OTA) and 2 repeated measures factors (3 daily time intervals [0500-1000, 1100-1400, and 1500-2100], crossed within 3 seasonal intervals [16 April-15 May, 16 May-15 June, and 16 June-15 July]. Multivariate tests (F approximations of Wilks' Lambda) were used to assess significance of the repeated measures factors.

## Behavior of Prairie Falcons in Territories

Field protocol.--We monitored 14 of the 28 instrumented falcons in their territories to determine prey delivery rates from 4 April - 3 July. Six of the territories were within the OTA shadow, and 8 were west of the OTA. These represent all of our study nesting areas within the OTA shadow and those with the most clearly observable scrapes west of the OTA shadow. Each territory was watched for an average of 74.3 hrs (range = 31 - 150) over 4.9 days (range = 2 - 10). Observations were made from blinds placed to optimize our view of the scrape and minimize observer-induced disturbance (distance from blind to aeries = 119 m, range = 72 - 240 m; following Holthuijzen 1990). Topographical features in 2 territories allowed us to see directly into the nest cavity; all other scrapes were viewed from below nest level. Blinds were not used in 3 territories (Hell Hole Gaging Station, Cattleguard Gate, and Mother Giant Upstream) because the pair appeared to be habituated to nearby human recreational activities. We observed only pairs that did not fail and those where the radio-tagged bird did not lose its transmitter.

We observed territories from 20 min before sunrise to 20 min after sunset. Each sampling day was divided in half, and 1 observer watched the scrape during each half-day. Observers replaced one another at midday, allowing us to keep a scrape under constant surveillance throughout the entire day. In total, we completed 66 full days of observation and 3 partial days.

To increase our independent samples of behavior, we maximized the number of territories observed rather than the number of days each territory was observed. Every nest was observed at least once during early brood-rearing (nestlings < 21 days old) and once during late brood rearing (nestlings 21-40 days old). On average, each territory was observed 1.9 days during early brood rearing (range = 1-3 days) and 2.3 days during late brood rearing (range = 1-5 days). An additional 12 days were spent observing the 6 OTA shadow territories during incubation (mean = 2 days per aerie, range = 1-4 days). Our observation schedule was not randomized due to logistical constraints (territories close to each other were observed during the same week) and military training schedules (territories in the OTA shadow were observed on firing and non-firing days).

Eight observers conducted all behavioral watches. Each person made morning and afternoon observations, and most made some observations at each site. Observers learned falcon behaviors by watching breeding peregrine falcons (*Falco peregrinus*) for 1 morning at the Peregrine Fund's World Center for Birds of Prey and spending 1 day in the field observing prairie falcons prior to making behavioral

observations. Observers watched nests with 10 x 50x binoculars and 15-45x spotting scopes.

We obtained complete counts of prey items delivered to the scrape and identified the sex of the bird making the delivery when bands or transmitters were visible. Deliveries were credited to the sex that brought the prey item into the territory, but because caching is common (Holthuijzen 1990), we were not always certain whether a given prey item was retrieved from a cache or freshly captured. Our sample of known prey recovered from caches indicates that females are responsible for most recoveries (11 of 13) and therefore any bias in our estimation of sex-specific prey delivery rates is likely to be an overestimation of female deliveries. However, our quantification of total prey items delivered to the scrape is unlikely to be a biased estimate of fresh items delivered to the territory (Holthuijzen's 1990 measure of prey delivery) because nearly every item cached is eventually retrieved and fed to the nestlings (Holthuijzen 1990).

We classified the prey delivered by species (Townsend's ground squirrel), genus (kangaroo rat [*Dipodomys* spp.]), or class (mammal, bird, reptile, or insect) when possible; other prey items were recorded as unidentified. Prey deliveries of insects were rare, and days on which they were delivered are excluded from our analyses.

We used laptop computers in the field to record observations on the parents' time budgets. The following behaviors were reliably recorded at each territory: (1) the time each parent spent within 5 m of the scrape, (2) the time each parent spent in the nesting territory, and (3) total time at least 1 parent attended the scrape. Time parents spent in the nest territory was assessed by visually scanning the territory from the blind. The time parents were visible in their territory was recorded as a measure of territory attendance. This may underestimate actual attendance because birds could perch in their territory, but out of our view. We also recorded the time spent perching, brooding, incubating, feeding young, and feeding self. We determined whether prey was cached, retrieved or transferred between parents and noted the occurrence of copulation, intra- and interspecific interactions, and human activity (presence of vehicles, construction crews, and recreation). Differences in the visibility of scrapes and our focus on prey deliveries precluded complete samples of these behaviors.

Analyses.--We tested the null hypothesis that military training does not influence prey delivery rate (# deliveries to the scrape/hr) or parental attendance by comparing behavior at sites in the OTA shadow to behavior at sites west of the OTA. For these tests the territory was the sampling unit.

We had complete observations at 14 nests and used a repeated measures ANOVA with 1 2-level between subjects factor (nesting areas in the OTA shadow versus west of the OTA). Behavior in the same territory when the young were < 21 days old versus 21-40 days old was 1 repeated measures factor. The other repeated measures factor, the behavior of males and behavior of females, was crossed within each nestling age class. This allowed us to test for 3 effects (proximity to the OTA, age of nestlings, and sex of parent) in 1 model. Univariate tests were conducted on the repeated measures factors because each measure only had 2 levels. Multiple observations of behavior within each age interval were averaged to increase the normality of the response variables. Percentages were transformed (arcsine of their square root) prior to analysis.

The effects of brood size and hatch date (number of days after the first clutch hatched) were investigated by correlating

these measures with our measures of parental attendance and prey delivery rate. We also used these 2 factors as covariates in the repeated measures ANOVAs described above. Homogeneity of slopes was tested and confirmed prior to analysis of covariance.

The influence of nestling age was further investigated by using each day of observation as an independent sample. We then correlated a daily average value for each behavior with the estimated average age of the chicks.

We sampled behavior of falcons nesting within the OTA shadow on 4 pairs of days (within 1 - 5 days of each other); 1 day in each pair was a day when the OTA ranges were not firing and the other day was a day when ranges were firing. We present these results without formal analysis because sample sizes are currently insufficient. Consecutive observations on firing versus non-firing days at 2 nesting areas west of the OTA served as controls.

**Behavior and Abundance of Raptors on Firing Ranges**

Field Protocol.--We monitored the abundance and behavior of raptors on 11 firing ranges for a total of 52 days (95 observer days) during May, June, July, and August 1991. These ranges are located inside the circular cinder Range Road and extend toward an artillery impact area (AIA, Fig. 2). Our study ranges included 5 tank training ranges (ranges 1, 5, 6, 10, 11), 2 small arms firing ranges (ranges 14, 15), 2 mortar ranges (ranges 26, 30), and 2 ranges utilized for a variety of driving and firing activities (ranges 20, 4).

Study areas on ranges include the firing fans and the areas adjacent to these fans. Firing fans are the areas impacted during training and, for our purposes, include the down-range impact area as well as the staging pads used for firing and the roadways upon which firing vehicles drive. We made our observations from high points located at the base of each range's firing fan that afforded a view of the fan as well as the less impacted adjacent areas. Fan areas were delineated from adjacent areas by permanent range markers or by prominent topographical features.

We scanned the fan and adjacent areas using 10 x 50x binoculars and variable power spotting scopes. Our scans were limited to a semicircle (in which the firing fan was centered) that extended to the horizon (Fig. 2). We began scanning at approximately 0700 hr and continued until 1500 hr (MST). Each scan lasted 15 min with 5 min separating consecutive scans. We counted the number of raptors observed during each scan and noted their behavior in and out of the firing fan during a 1-min focal sample. Raptors were identified to genus or species when possible or recorded as unknown if identification was not possible. We peripherally kept track of individuals after the 1-min focal sample to avoid recounting birds within a scan. Sightings of birds on the horizon were noted, but excluded from analyses because they were considered to be beyond the area of military activity. Recorded raptor behaviors are listed in Appendix B.

Each range was sampled on days that firing occurred (hot days) and on days when no firing occurred (cold days). We conducted pairs of observations on hot and cold days on each of the 11 ranges. The specific actions of the military using the range (Appendix B) on hot days were recorded.

Each daily survey of raptor and military activity was conducted by a single observer. Throughout the course of our study, 5 individuals acted as observers. Each individual surveyed each range at least once on a hot day and once on a cold day. Observers met periodically throughout the

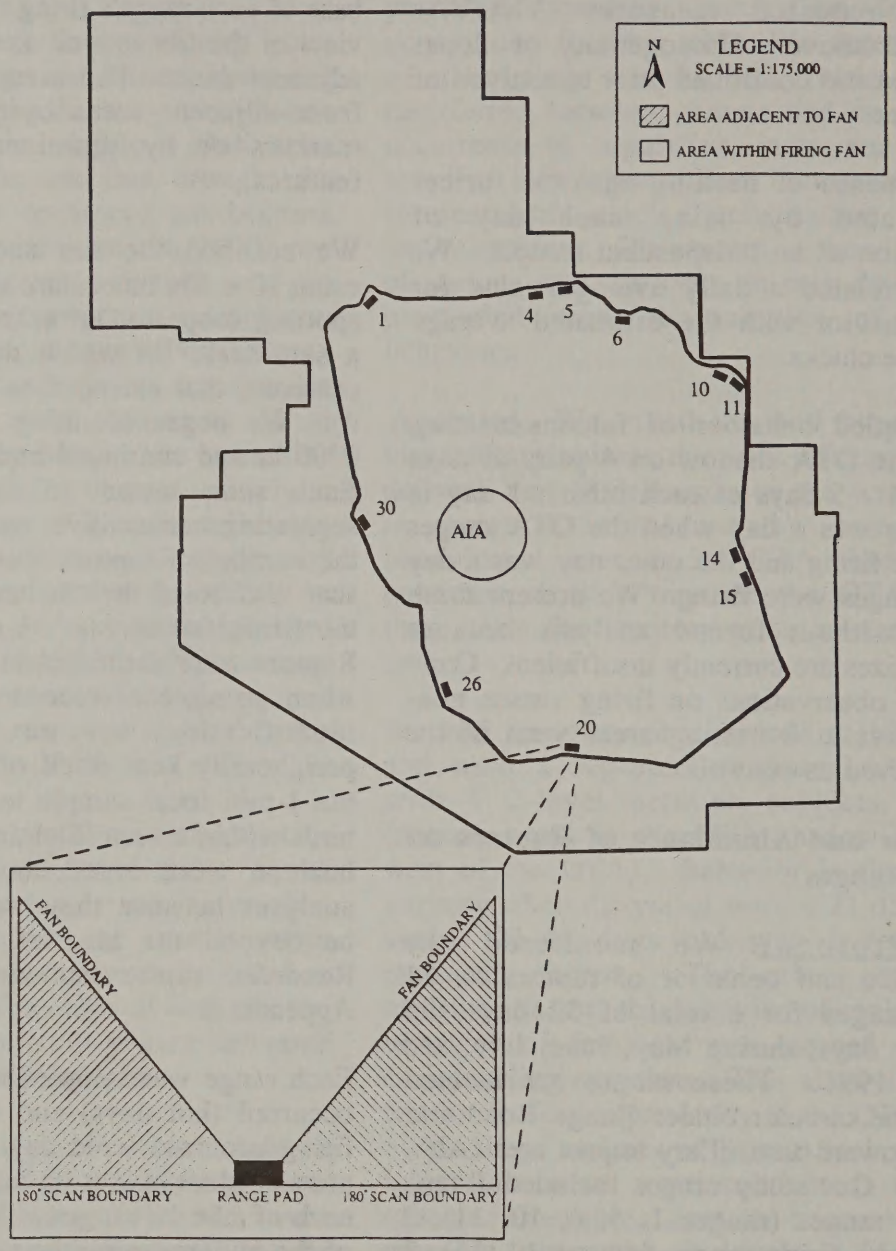



Fig. 2. Military training ranges where observations were conducted and detail of 1 sampling area. Firing fans and adjacent areas are centered on the firing pad at each range. We scan the entire 180 degree area.

study to compare observation techniques and minimize inter-individual differences.

Analyses.--We designed an experiment utilizing 4 tank training ranges, 1 artillery range, and 1 small arms range to assess the influence of the type of military training on raptor use of firing ranges. We sampled each range 6 times during our study season (each range was sampled on 3 pairs of hot and cold observation days). The pairs were distributed throughout the season and included an early season sample, a mid-season sample, and a late season sample. We averaged the detection rates acquired from the 6 15-min scans within each 2-hr block to increase the normality of responses. These average responses were analyzed with a 2-factor, repeated measures ANOVA; time of day (4, 2-hr levels) was crossed within activity of the range (hot or cold). Separate analyses were run on early, mid, and late season samples. Multivariate tests (F approximation of Wilks' Lambda) were used to appraise the significance of time of day and the interaction of time and firing activity because time of day had more than 2 levels.

We used all of our observations on all ranges to test for the influence of specific military activities on the abundance of raptors using firing ranges. We averaged 15-min scan counts that were conducted within an hr under the same level of military activity. To reduce dependence among multiple hourly samples we averaged hourly samples taken on a given type of military activity on the same day to create 1 sample for each military activity each day. Raptor abundance was compared between types of military activity with a 1-way ANOVA using temperature as a covariate. Homogeneity of slopes was tested and confirmed prior to analysis of covariance.

Military training was not constant within our sampling units. We scored each hourly sample as having no military activity, constant military activity, or intermittent activity (samples that included activity punctuated by bouts of inactivity). We compared raptor abundance between periods differing in the consistency of activity using a 1-way ANOVA with temperature as a covariate. Homogeneity of slopes was confirmed prior to analysis of covariance.

We analyzed the influence of training on raptor behavior by comparing behaviors exhibited by birds in and out of the firing fan on hot versus cold days. Four species groups were analyzed separately (northern harriers, *Circus cyaneus*, Falcons [prairie falcons and American kestrels, *Falco sparverius*], Buteos and Eagles [red-tailed hawks, *Buteo jamaicensis*, rough-legged hawks, *Buteo lagopus*, Swainson's hawks, *Buteo swainsoni,* ferruginous hawks, *Buteo regalis*, golden eagles, and unidentified Buteo species], and Owls [burrowing owls, *Athene cunicularia* and short-eared owls, *Asio flammeus*]). Preliminary analyses indicated that initial observations were insufficient to characterize raptor behavioral repertoires; therefore we scored each 1-min focal sample for the presence or absence of each behavior. This produces a frequency distribution of behaviors based on a sample size equal to the number of focal samples. Such frequency distributions are amenable to standard contingency table analyses (Hejl et al. 1990).

We compared behavioral repertoires of raptors observed in versus out of the firing fans on hot versus cold days using hierarchical log-linear models. To increase the counts in some behavior cells we lumped the behavioral repertoires into 9 categories (1: perching; 2, 3, 4: traveling flight [flapping and gliding flight] at each of 3 height categories [0-3 m, 4-10 m, > 10 m]; 5, 6, 7: stationary flight [soaring and hovering] at each of the 3 previous height categories; 8: maneuvers [intraspecific, interspecific, and complex individual maneuvers]; and 9: attacks [attacks and dives]). The statistic

of interest is the test of the 3-way interaction between behavior, range activity, and location with respect to the firing fan. A significant interaction between these factors indicates that birds change their behavior in the firing fan relative to their behavior out of the fan depending upon the activity on the range. If the 3-way interaction is not significant, then the 2-way interactions (behavior versus location with respect to the firing fan; behavior versus range activity) are further used to test for general behavioral responses due to fan location and range activity.

**Golden Eagle Observations and Trapping**

We randomly selected historically occupied golden eagle territories (defended areas including nesting and foraging sites) from each of 2 categories; OTA shadow and outside OTA shadow, but within the Integration Study Area. The habitat in each territory was classified as either burned (> 50% of the area within a 2.66-km radius circle centered at traditionally used nests had been burned) or unburned (< 30% of the area within the 2.66-km radius circle had not been burned) based on fire activity during the past 10 years. Three traditional territories were selected from each category, and the number of burned and unburned territories was equalized without regard to OTA category.

We began scouting territories in January to determine occupancy and use patterns of resident adults. Territories that we found to be unoccupied were replaced from a list of alternate sites. Once occupancy was confirmed, we placed skinned calf carcasses at potential trap sites within the territory. We monitored carcasses from a distance to observe use by eagles and to distinguish residents (paired individuals synchronizing their activities within a traditional nesting area) from wintering birds (single birds moving without regard for the nesting area boundary). Traps were placed near bait sites or other carcasses that residents were using. We went to the site at least 2 nights before a trapping attempt and set up a radio-triggered bow net and blind (within 500 m of the trap). We returned to trap sites before dawn, test fired and camouflaged the bow, and secured a lure animal or bait within the bow. An observer stayed in the blind and a support person left the area but maintained radio contact. Observers remained in the blind until midday, and left only if the support person reported no eagles visible in the area. We investigated alternate trapping methods, including noosed lures or bait and padded leghold trap sets. Noosed lures were infrequently used, and we determined them inappropriate for most trapping situations. Procedures for placing legholds were similar to those for bow nets except that traps were set before daybreak on the morning of the trapping attempt and the use of blinds was not necessary because leghold sets were monitored from a distant vantage point.

Captured eagles were hooded and restrained during data collection. We measured weight using Chatillon scales (3 kg) with the bird in an abba (cloth wrap with pockets for wrist of wing). Bill depth, hallux length (straight), span of right footpad, culmen length, and head depth were all measured using 15.2 cm (6 in) dial calipers. One wing was freed from the abba for measurement of wing chord, wing width and wing span (2x measure from middle of back to longest primary with wing fully extended) using a folding metric ruler. We removed the abba for measurement of body circumference (using cloth tape) and placement of the backpack transmitter. We recorded condition by estimating the slope of the pectoralis at the sternum and the amount of subcutaneous fat.

Eagles were outfitted with loose fitting 75-g backpack packages (65-g solar-powered transmitters plus 10-g Teflon webbing and leather sternum patch). Harness design followed Buehler et al. (in press) with the addition of a leather sternum patch. Initially,

we secured transmitters by threading Teflon straps through a leather patch at the middle of the sternum, knotting all the straps on the distal side of the leather patch. The removal of a transmitter by 1 captured adult led us to modify the method of attachment (enlarging tubes through which Teflon ribbon passed) so we could secure the transmitter by passing straps (from opposite directions) through the tubes at either end of the transmitter and sewing the Teflon ribbon together at either end of the tube.

Instrumented eagles were followed 3-4 days per week when they were within the study area and sporadically when they left the study area. We homed in on the transmitters until visual contact was made and then recorded the behavior and location of instrumented birds.

## RESULTS

### Activity of Prairie Falcons Inferred From Radio Telemetry

Influence of telemetry packages.--Before we report on the movement of radio-tagged falcons it is imperative that we understand if and how these packages affected the birds.

We observed little immediate change in behavior when we released newly instrumented birds. Falcons behaved normally during the first hr that they wore transmitters; they typically preened around their transmitter and harness and picked at their bands, but quickly resumed courtship, incubation and brood-rearing activities. We observed 4 instrumented falcons copulate and 7 return to their scrape within 1 hr of release. One instrumented female received a prey delivery from her mate during this time. On the day after instrumentation we observed all birds engaged in breeding activities (courtship, copulation, incubation, brood-rearing, or patrolling their territories). Capture and radio-marking did not appear to reduce a falcon's motivation to pursue prey as 1 female was recaptured stooping a rock dove 1 day after initially being fitted with a transmitter.

Instrumented falcons did not have significantly lower fledging success than non-instrumented control birds. Eighty-one percent of 42 control pairs with known nesting fates successfully fledged young compared to 73% of 26 instrumented pairs (Likelihood-ratio $G^2_{(1)} = 0.57$, $P = 0.45$). The average number of fledglings per pair produced by 32 control pairs also did not differ from the average number produced by 24 radio-tagged birds (mean control = 3.06, SD = 2.06; mean instrumented = 2.88, SD = 2.09; $t = 0.34$, 54 df, $P = 0.74$). Likewise, the number of fledglings produced per successful pair was not associated with the presence of radio transmitters (mean control = 4.08, SD = 1.18, $n = 24$; mean instrumented = 4.06, SD = 1.09, $n = 17$; $t = 0.07$, 54 df, $P = 0.95$).

Pairs that included females with transmitters tended to have higher failure rates (37.5% of 16) than pairs including radio-tagged males (10% of 10). However, this difference was not significant ($G^2_{(1)} = 2.62$, $P = 0.11$). A closer look at these data suggest that the preponderance of failures by pairs with a radio-tagged female resulted because pairs with females captured early in the breeding cycle (before incubation) had high failure rates. Five females were caught during this time, and 4 of their nesting attempts eventually failed (only 1 of 9 males caught prior to incubation had nests that failed). Eleven females were caught later in the nesting cycle, and only 2 had failed nesting attempts (no males caught at this time had failed nesting attempts).

Male falcons with transmitters and males without transmitters (those paired to radio-tagged females) provisioned their nestlings and tended their nests and territories at similar rates. Regardless of nestling age, prey delivery rate was not associated with

the presence of a transmitter (nestlings < 21 days old: instrumented males: n = 9, mean = 0.27/hr, SD = 0.10; non-instrumented males: n = 5, mean = 0.23/hr, SD = 0.04; t = 0.77, 12 df, P = 0.46; nestlings 21-40 days old: instrumented males: n = 9, mean = 0.20/hr, SD = 0.06; non-instrumented males: n = 5, mean = 0.16/hr, SD = 0.15; t = 0.84, 12 df, P = 0.42). Attendance at the nest and in the territory was statistically similar for males with and without transmitters when nestlings were < 21 days old (transformed values: attendance at nest: mean instrumented = 16.9, n = 9, SD = 8.7; mean non-instrumented = 16.1, n = 5, SD = 11.8; t = 0.15, 12 df, P = 0.88; attendance in territory: mean instrumented = 30.2, n = 9, SD = 5.2; mean non-instrumented = 27.1, n = 4, SD = 9.6; t = 0.78, 11 df, P = 0.45). Sample size was too small to statistically assess attendance when nestlings were 21-40 days old (transformed values: attendance at nest: mean instrumented = 10.3, n = 9, SD = 9.4; mean non-instrumented = 3.9, n = 3, SD = 2.9; attendance in territory: mean instrumented = 30.0, n = 9, SD = 13.7; mean non-instrumented = 27.1, n = 2, SD = 11.5).

Prey delivery rates by females also were not associated with the presence of radio transmitters. Prey delivery to nestlings < 21 days old was unaffected by radio transmitters (mean instrumented = 0.13/hr, n = 5, SD = 0.09; mean non-instrumented = 0.25/hr, n = 9, SD = 0.15; t = 1.6, 12 df, P = 0.13). Likewise, delivery of prey to nestlings 21-40 days old was unaffected by the presence of transmitters (mean instrumented = 0.15/hr, n = 5, SD = 0.07; mean non-instrumented = 0.21/hr, n = 9, SD = 0.12; t = 0.98, 12 df, P = 0.35). The trend for females with radios to deliver fewer prey per hr to their nestlings did not translate into fecundity differences between instrumented and non-instrumented females; both groups reared similar numbers of fledglings (mean instrumented = 4.1 fledglings/successful attempt, n = 9, SD = 1.05; mean non-instrumented = 4.0 fledglings/successful attempt, n = 8, SD = 12; t = 0.20, 15 df, P = 0.84).

Radio-tagged females spent proportions of their time at their scrapes and in their territories similar to non-radio-tagged females. Attendance rates were statistically indistinguishable when nestlings were < 21 days old (transformed values: attendance at the nest: mean instrumented = 31.7, n = 5, SD = 11.7, mean non-instrumented = 39.6, n = 9, SD = 11.7; t = 1.2, 12 df, P = 0.25; attendance in territory: mean instrumented = 46.0, n = 4, SD = 5.4, mean non-instrumented = 46.9, n = 9, SD = 10.8; t = 0.16, 11 df, P = 0.88). Samples were insufficient to statistically assess differences in attendance when nestlings were 21-40 days old (transformed values: mean instrumented = 8.9, n = 3, SD = 3.7; mean non-instrumented = 16.6, n = 9, SD = 11.2; attendance in territory: mean instrumented = 32.2, n = 2, SD = 23.5; mean non-instrumented = 39.8, n = 9, SD = 15.5).

Radio-tagged falcons reared nestlings of similar or greater weight than control falcons. We divided nestlings into large (presumably female) and small (presumably male) categories based on footpad. Two mutually exclusive groups were defined by separating birds with footpads less than 86 mm from birds with larger footpads (Fig. 3). Large nestlings reared by radio-tagged birds and those reared by untagged birds had similar weights (n = 30 instrumented birds: mean = 839.2 g, SD = 73.9; n = 49 controls: mean = 829.5 g, SD = 50.5; $F_{1,75} = 0.004$, P = 0.95 controlling for length of the seventh primary and brood size). Small nestlings reared by radio-tagged birds were significantly heavier than those reared by control birds (n = 25 radio birds: mean = 600.6 g, SD = 55.7; n = 44 controls: mean = 557.6 g, SD = 25.1; $F_{1,65} = 11.5$, P = 0.001 controlling for length of the seventh primary and brood size).

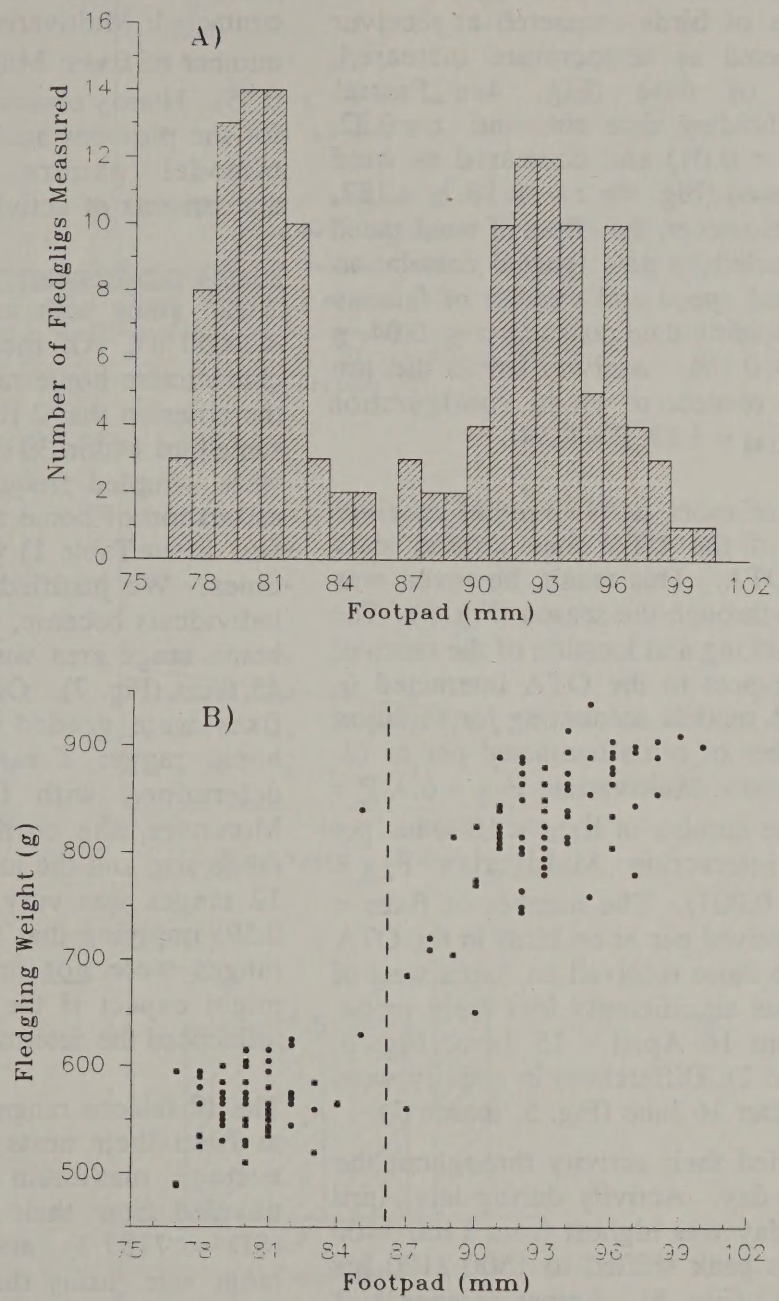



Fig. 3. Distribution of footpads of 148 nestling prairie falcons (A), and the relationship between nestling weight and footpad length (B). Nestlings (29-31 days old) form 2 distinct distributions based on footpad length, and groups separated on the basis of footpad length differ greatly in body mass.

General patterns of activity.--Weather influenced the movement (and/or our ability to detect movement) of radio-tagged falcons. The number of birds contacted at receiver sites increased as temperature increased, regardless of date (Fig. 4a; Partial correlation holding date constant: $r = 0.32$, $n = 152$, $P < 0.01$) and decreased as wind speed increased (Fig. 4b; $r = -0.18$, $n = 152$, $P = 0.03$). However, the effect of wind speed was confounded by date (partial correlation between wind speed and number of falcons contacted, holding date constant: $r = -0.04$, $n = 152$, $P > 0.10$). Activity levels did not differ with respect to cloud configuration (Fig. 4c; $F_{3,148} = 1.12$, $P = 0.34$).

Falcons were more active around receiver sites west of the OTA than around sites inside the OTA. This result, however, was not uniform through the season (Fig. 5). The month of tracking and location of the receiver site with respect to the OTA interacted in our ANOVA models accounting for variation in the number of birds contacted per hr (2-way interaction: Multivariate $F_{2,3} = 6.9$, $P = 0.08$) and the number of fixes < 1000 ha per hr (2-way interaction: Multivariate $F_{2,3} = 201.7$, $P < 0.001$). The number of fixes < 1000 ha received per hr on birds in the OTA compared to those received on birds west of the OTA was significantly less early in the season (from 16 April - 15 June; Fig. 5, season 1 and 2). Differences in activity were negligible after 16 June (Fig. 5, season 3).

Falcons varied their activity throughout the course of a day. Activity during late April and early May was highest from 1100-1400 hrs, but this peak shifted to 1500-2100 hrs after 16 May (Fig. 5). Across seasons 1, 2 and 3, the number of fixes < 1000 ha received per hr increased through the day (Multivariate $F_{2,3} = 9.9$, $P = 0.05$), but the number of birds contacted per hr did not increase through the day (Multivariate $F_{2,3} = 3.0$, $P = 0.20$). The tendency for daily activity peaks to shift from midday to later in the afternoon as the season progressed was not significant (2-way interaction between season and time of day; number of birds contacted: Multivariate $F_{4,1} = 5.2$, $P = 0.32$; number of fixes: Multivariate $F_{4,1} = 4.2$, $P = 0.35$). Hourly observations had to be lumped for the previous analysis, which obscures a bimodal pattern evident in hourly assessments of activity (Fig. 6).

Home range characteristics.--We obtained 2012 fixes with associated error ellipses < 1000 ha. Of these, 1275 were used to characterize home ranges because they met the criterion that 2 fixes not be taken on the same bird within 30 min. Twelve individuals were sampled frequently enough to allow estimation of home range. These birds (the first 12 in Table 1) were located at least 47 times. We justified the selection of these individuals because, on average, 75% of the home range area was sampled after taking 45 fixes (Fig. 7). Occasionally, many fewer fixes were needed to describe a falcon's home range; 2 ranges were completely determined with fewer than 45 fixes. Moreover, the correlation between home range size and the number of fixes for these 12 ranges was very weak ($r = -0.18$, $P = 0.59$) implying that less frequently sampled ranges were not unusually small, as one might expect if the intensity of sampling influenced the determination of home range.

The 12 falcons ranged an average of 7416.0 m from their nests (SD = 2713.4). The average maximum distance these birds traveled from their nests was 20,676.3 m (SD = 7187.3), and their average home range size (using the 95% use area around the harmonic mean) was 21,387.7 ha (SD = 12,205.0). The spatial use patterns of these 12 birds are shown in Fig. 8. We present several other measures of home range size, travel distance, and home range shape in Table 1. However, the harmonic mean estimation technique is most suitable for prairie falcon spatial use patterns because

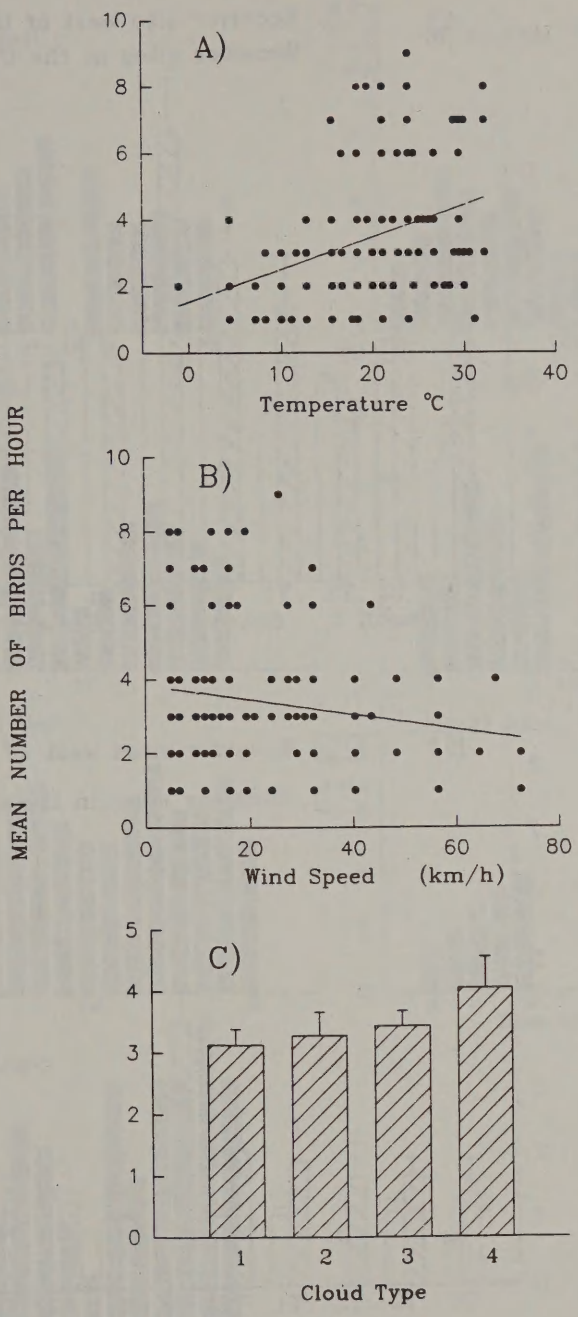



Fig. 4. Correlations between 3 weather variables and the average number of radio-tagged falcons contacted per hr from receiver sites throughout the study area. Temperature was measured in C on a pocket thermometer. Wind speed was estimated to the nearest 10 km/hr. Cloud type categories were assigned as: 1 = clear, 2 = ≤ 50% coverage of any cumulus cloud, 3 = any coverage of cirrus and stratus cloud, 4 = > 50% coverage of cumulus clouds. One observer made all of these observations.

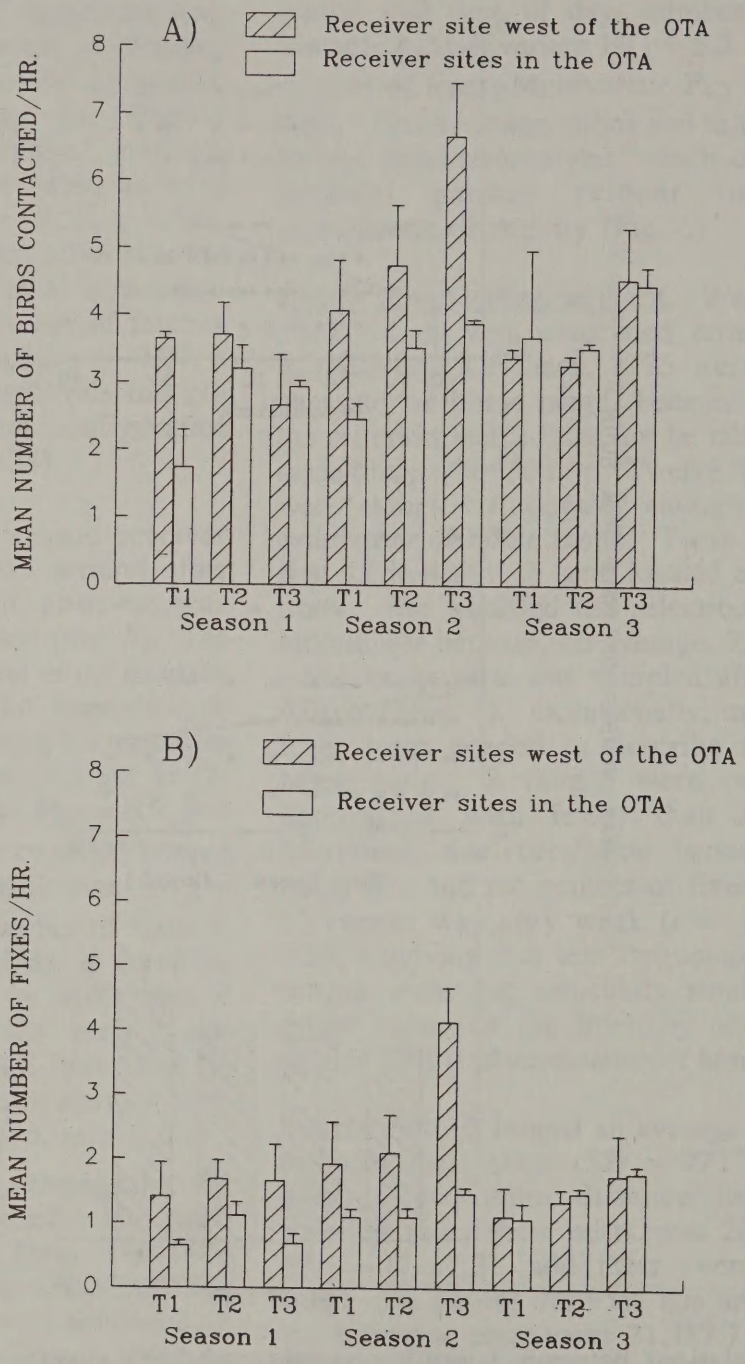



Fig. 5. Changes in radio-tagged falcon activity through the seasons (season 1 = 16 April - 15 May, season 2 = 16 May - 15 June, season 3 = 16 June - 15 July) and through the day (T1 = 0500-1000 hr, T2 = 1100-1400 hr, T3 = 1500-2100 hr). Mean activity +1 SE are shown for 3 receiver sites in the OTA and 3 sites west of the OTA.

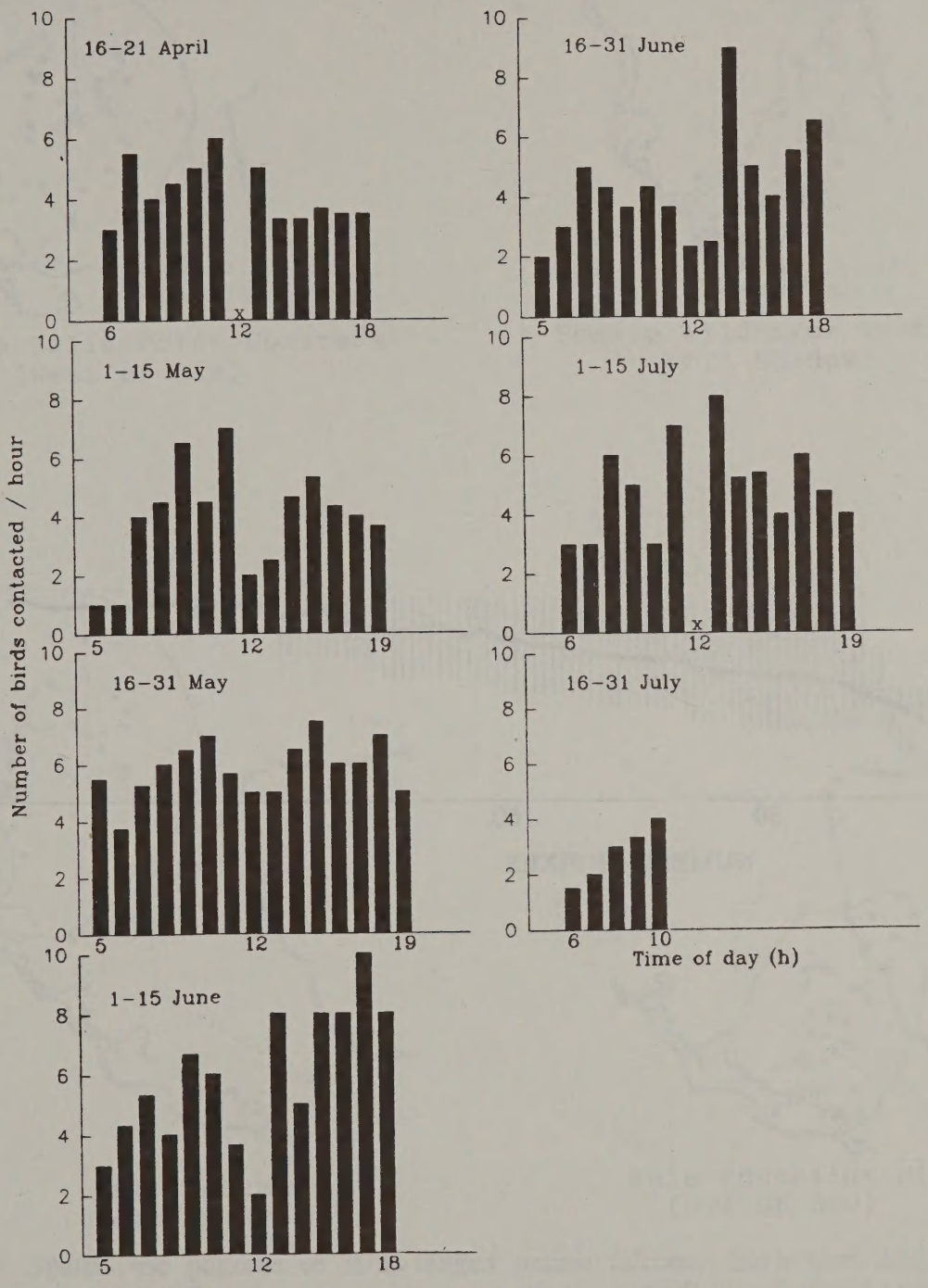



Fig. 6. Changes in radio-tagged falcon activity through the daylight hr and across the season at a receiver site west of the OTA (Initial Point). Start and end times for observations made in each season are listed on the horizontal axis. An x indicates no observations were made during that hr.

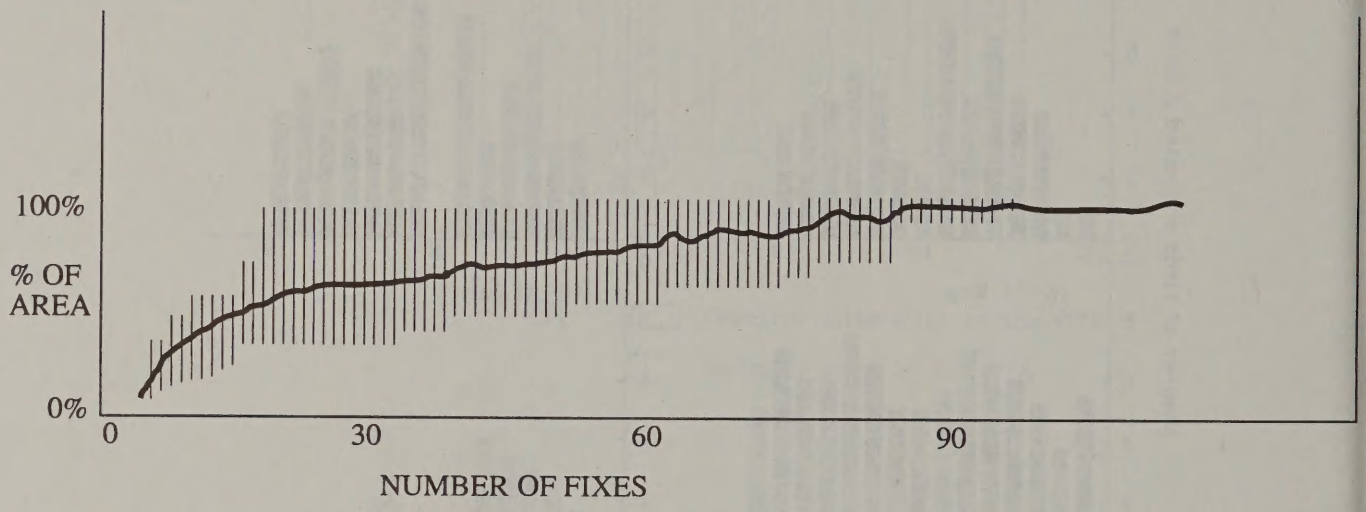
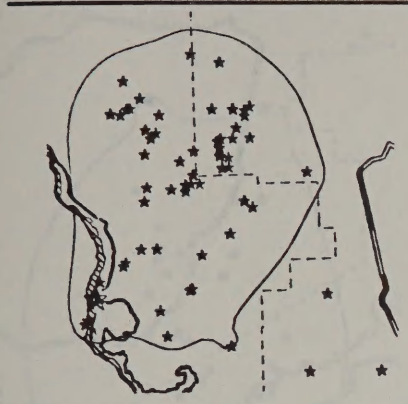
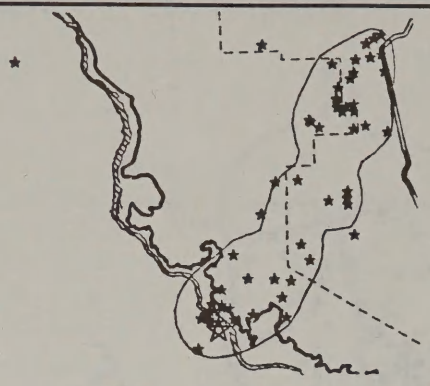


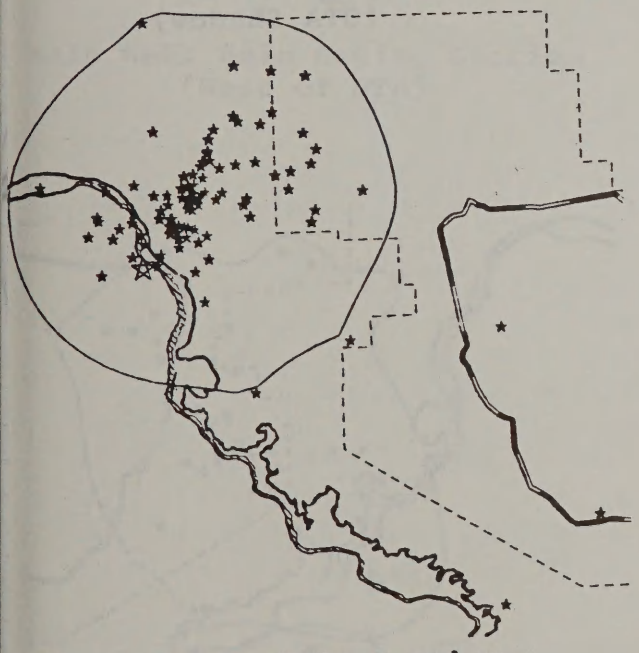

Fig. 7. The increase in percentage of 10 falcons' home ranges as a function of sampling effort (number of fixes < 1000 ha). The line indicates the average increase and the vertical lines indicate the range of values. Fixes are listed in chronological order. Only falcons with at least 60 samples were included.



Female Balls Point Upstream
(West of OTA)



Female Wildhorse Butte NE
(OTA Shadow)

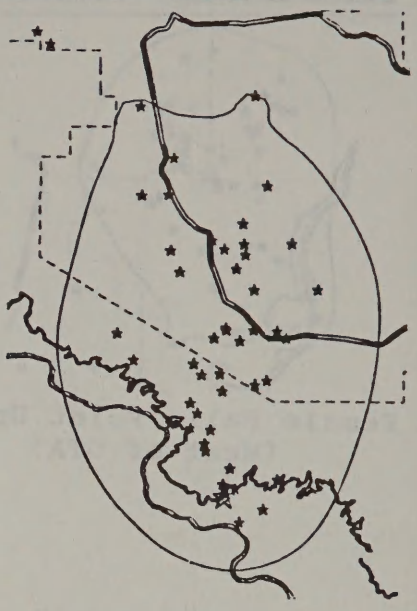


Male Beecham
(West of OTA)

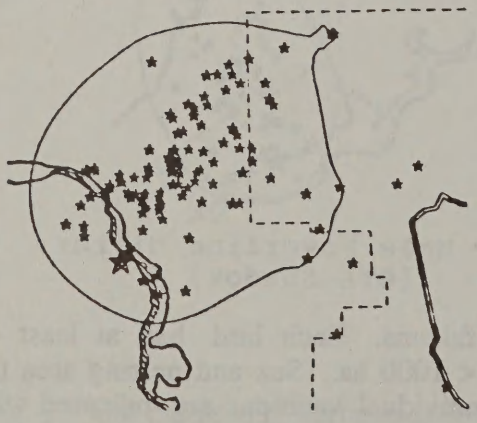
Male Powerline Mirror
(OTA Shadow)

Fig. 8. Spatial use patterns of radio-tagged prairie falcons. Each bird had at least 45 estimates of their location with error ellipses < 1000 ha. Sex and nesting area for each individual are listed below each map. Individual locations are indicated with solid stars and aeries are indicated with open stars. The 95% core area determined by harmonic mean analysis is indicated by the thin, solid line. The Snake River (hatched area), north canyon edge (thick, solid line), OTA boundary (thin, dashed line) and range road (thick, dashed line) are shown for orientation. Each map is drawn to the same scale (1: 400,000).

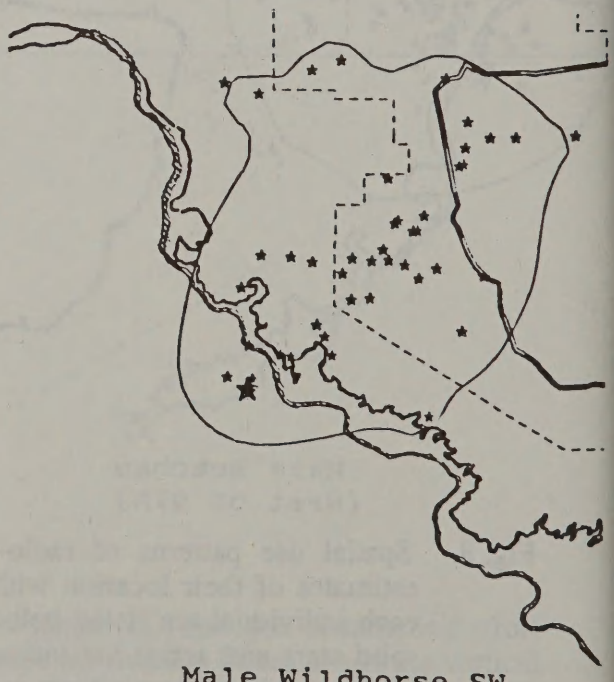
Male Priest Upper
(West of OTA)



Male CSJ
(OTA Shadow)



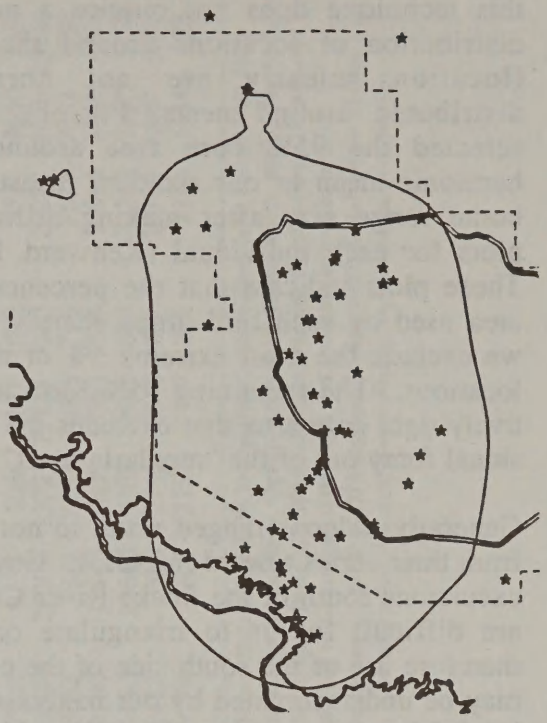
Male Bitch
(West of OTA)



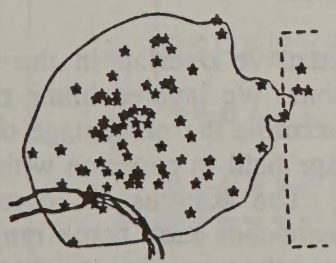
Male Wildhorse SW
(OTA Shadow)

Fig. 8. Continued.

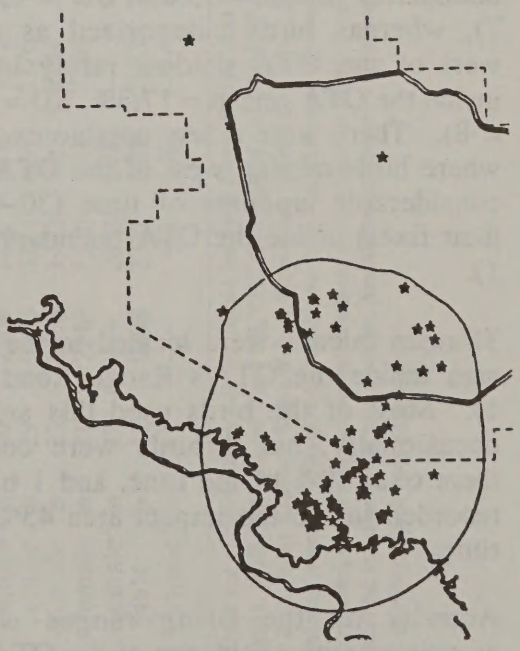
Male Hell Hole Gaging Station
(West of OTA)



Female Cabin
(OTA Shadow)



Male Beercase Draw
(OTA Shadow)



Male Cattleguard Gate
(West of OTA)

Fig. 8. Continued.

this technique does not require a normal distribution of locations around the nest (locations clearly are not normally distributed around nests, Fig. 8). We selected the 95% core area around the harmonic mean as our standard measure of home range size after making utilization plots for each individual (Kenward 1987). These plots indicate that the percentage of area used by each bird drops sharply when we exclude the most extreme 5% of the fix locations. The remaining 95% form a relatively tight core area that excludes the occasional foray out of the "regularly-used" area.

Generally, falcons ranged north to northeast from their aeries toward the OTA. However, excursions south of the Snake River Canyon are difficult for us to triangulate on and therefore use of the south side of the canyon may be underestimated by our methods. All but 3 falcons ranged into the OTA during the season, and 5 birds were located in the OTA on half or more of our samples (Table 1). Birds categorized as nesting in the OTA shadow were often located inside the OTA boundaries (mean = 55.6%, SD = 13.1, $\underline{n}$ = 7), whereas birds categorized as nesting west of the OTA shadow rarely ventured inside the OTA (mean = 17.3%, SD = 15.0, $\underline{n}$ = 8). There were a few notable exceptions where birds nesting west of the OTA spent considerable amounts of time (30-40% of their fixes) inside the OTA boundary (Table 1).

Thirteen falcons were located in the impact area inside the OTA's Range Road (Table 1). Most of the birds used this area only occasionally, but 4 birds were contacted there over 20% of the time, and 1 bird was recorded inside the impact area 45% of the time.

Activity on the firing ranges was not associated with avoidance of the OTA or the impact area. We tracked falcons on 76 days when firing occurred on the ranges and 21 days when firing did not occur (78.4% of days had firing). The distribution of fixes on birds inside the OTA boundary versus those outside of the boundary did not differ from the expectation that 78.4% of fixes inside the OTA should occur on days with firing ($X^2_{(1)}$ = 4.29, $\underline{P} > 0.10$). However, the trend was for more fixes than expected to occur inside the OTA on non-firing days (88 of 335 fixes occurred inside the OTA on non-firing days). Use of the area inside the range road was not influenced by activity on the ranges (19 of 83 fixes were on cold days; $X^2_{(1)} = 0.87$, $\underline{P} > 0.10$).

Birds nesting in the OTA shadow ranged farther than birds nesting west of the shadow. We had adequate samples for 6 (2 females, 4 males) birds nesting in the OTA shadow and 6 (1 female, 5 males) birds nesting west of the OTA. Birds in the OTA shadow differed from those west of the OTA by traveling farther on average from their nest, ranging to more extreme maximum points from their nests, and covering larger home ranges (Fig. 9a; MANOVA testing these 3 measures of spatial use simultaneously: Multivariate $F_{3,8} = 4.5$, $\underline{P}$ = 0.04).

Females tended to range slightly farther afield than males (Fig. 9b). However, we adequately sampled home ranges of only 3 females, and 1 of these (Cabin nesting area; Table 1) ranged extensively, thereby strongly influencing the female mean. We did not analyze formally differences in home range characteristics between sexes due to small sample size.

There was extensive overlap in the home ranges of falcons. We layered home ranges in order to determine the percentage of area each home range held in common with each other range. The Ranges IV computer program superimposes each home range on top of every other range so that 132 comparisons among our 12 ranges are made. Fifty-two (39.4%) pairs of ranges held no area in common (they were at opposite ends

Table 1. Home range characteristics of paired prairie falcons determined from radiotelemetry in 1991.

| Nest[a] Area | Sex | OTA | N | Mean distance from: Nest | Hc | Ac | Hc-Nest | Max distance from: Nest | Hc | Ac | Harmonic Mean Home Range Max | 95% | 90% | 50% | Convex Polygon Home Range Max | 90% | 70% | 50% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BrcsD | Male | y | 88 | 6493 | 1028 | 5070 | 3057 | 27580 | 25140 | 21990 | 86195 | 22416 | 13028 | 2075 | 34160 | 9945 | 4769 | 1380 |
| Cabin | Female | y | 69 | 12720 | 3481 | 8435 | 8356 | 32250 | 24440 | 20740 | 92517 | 45073 | 44703 | 8944 | 51460 | 30400 | 19020 | 10730 |
| Bitch | Male | n | 113 | 6861 | 1156 | 4168 | 5388 | 18480 | 18490 | 17620 | 63139 | 20471 | 1124 | 3090 | 24120 | 13250 | 5665 | 3495 |
| PrUp | Male | n | 89 | 6050 | 1221 | 4262 | 3683 | 20640 | 19910 | 19040 | 72988 | 19402 | 13395 | 3693 | 23480 | 10150 | 5906 | 2785 |
| CSJ | Male | y | 48 | 9508 | 2405 | 6094 | 108 | 26380 | 26440 | 18220 | 40354 | 33100 | 17645 | 4636 | 21350 | 12700 | 8575 | 4359 |
| WHSW | Male | y | 47 | 10640 | 2016 | 6692 | 89 | 22020 | 21970 | 27780 | 107825 | 32591 | 29826 | 5430 | 43400 | 21950 | 10840 | 7486 |
| BPtUp | Female | n | 59 | 8612 | 2197 | 4633 | 10342 | 15460 | 14780 | 13780 | 33811 | 17576 | 12255 | 2935 | 16880 | 13320 | 8254 | 6359 |
| Beech | Male | n | 95 | 5999 | 1448 | 4222 | 4591 | 27270 | 26790 | 26010 | 120765 | 31172 | 14543 | 3062 | 40010 | 12580 | 5384 | 2969 |
| HHGS | Male | n | 86 | 2535 | 714 | 1740 | 2178 | 6256 | 6989 | 6386 | 8833 | 2676 | 1925 | 698 | 3760 | 2030 | 1385 | 794 |
| WHNE | Female | y | 60 | 8367 | 1027 | 6350 | 889 | 17890 | 17420 | 16110 | 47742 | 8526 | 5997 | 1961 | 20760 | 9998 | 5488 | 3500 |
| CGG | Male | n | 77 | 5243 | 2033 | 3552 | 2061 | 12870 | 10150 | 8663 | 15891 | 12232 | 10028 | 2923 | 10290 | 7405 | 5155 | 2743 |
| PlMir | Male[b] | y | 63 | 5964 | 61 | 3852 | 12854 | 10201 | 7430 | 18040 | 56610 | 11417 | 9960 | 2704 | 19820 | 8097 | 5361 | 3323 |
| Fang | Female[b] | n | 46 | ----- | 1363 | 2499 | ----- | ---- | 9637 | 9375 | 14768 | 11166 | 4064 | 1074 | 6082 | 2801 | 1698 | 751 |
| PChm | Female | n | 42 | 3679 | 383 | 2440 | 4232 | 9241 | 5876 | 6049 | 5726 | 3907 | 3399 | 571 | 4292 | 2918 | 1406 | 1141 |
| OgRdD | Female[b] | n | 41 | ----- | 2036 | 4428 | ----- | ---- | 20990 | 22410 | 61754 | 8869 | 8159 | 4691 | 13390 | 5875 | 4309 | 2982 |
| MGUp | Female | n | 38 | 6058 | 2410 | 4111 | 2512 | 10410 | 9457 | 8001 | 11561 | 9775 | 8212 | 2079 | 10610 | 9303 | 6344 | 3724 |
| PrR1 | Female[b] | n | 34 | 3931 | 1262 | 2690 | 252 | 29777 | 7315 | 6322 | 5244 | 4146 | 4018 | 805 | 4411 | 3425 | 1824 | 542 |
| TomBW | Female | n | 34 | 12880 | 3108 | 7986 | 15537 | 15080 | 20210 | 15690 | 42849 | 34377 | 27286 | 5787 | 34130 | 25820 | 18080 | 12970 |
| FvrB | Female | n | 30 | 7904 | 1237 | 5416 | 1271 | 13560 | 122290 | 7903 | 9152 | 5086 | 4131 | 1072 | 9731 | 9640 | 7389 | 3547 |
| Sw1D | Female | n | 29 | 9203 | 3124 | 6280 | 2176 | 18130 | 16860 | 12800 | 27000 | 23721 | 12423 | 3230 | 22270 | 17670 | 13140 | 4187 |
| BBGE | Female | n | 23 | 5698 | 1452 | 3469 | 6734 | 8879 | 9501 | 8232 | 7874 | 7287 | 4016 | 716 | 7678 | 7252 | 1993 | 1743 |
| BBH | Female | n | 21 | 7246 | 1960 | 3798 | 7746 | 17080 | 11150 | 12780 | 19448 | 10859 | 8561 | 1239 | 10920 | 6080 | 4059 | 3249 |
| BBPl | Female[b] | n | 17 | ----- | 2898 | 6947 | ----- | ----- | 19890 | 21540 | 19647 | 19382 | 16481 | 2879 | 22260 | 10110 | 3179 | 1970 |
| FwnHb | Male | y | 11 | 9498 | 2337 | 5035 | 7683 | 16090 | 10670 | 8422 | 3350 | 2948 | 2948 | 657 | 10110 | 8887 | 5327 | 766 |
| Tick3 | Female[b] | n | 11 | ----- | 455 | 3460 | ----- | ----- | 10730 | 9170 | 2386 | 2157 | 2157 | 261 | 2163 | 1654 | 223 | 97 |

[a] Nesting areas are abbreviated as follows: BrcsD-Beercase Draw, PrUp-Priest Upper, WHSW-Wildhorse SW, BPtUp-Balls Pt Upstream, Beech-Beecham, HHGS-Hell Hole Gaging Station, WHNE-Wildhorse Butte NE, CGG-Cattleguard Gate, PlMir-Powerline Mirror, PChm-Peregrine Chimney, OgRD-Ogden Rock Downstream, MGUp-Mother Giant Upstream, PrR1-Priest Rapids I, TomBW-Tom Butte West FvrB-Fever Basin, Sw1D-Swan I Draw, BBGE-Balls Basin GE, BBH-Balls Basin Hamer, FwnHb-Fawn Humpback, Tick3-Tick III. Falcons from Priest Rapids II, Wildhorse Face Fenceline, and Henderson Draw are not listed due to transmitter difficulties and resulting lack of data.

[b] Nest attempt failed or not initiated; no information for nest location is listed for birds that did not initiate a scrape OTA: y=OTA shadow, n=west of OTA N=Number of fixes with error ellipses <1000 ha Hc=Harmonic Mean center, Ac=Arithmatic center Harmonic mean: Hr=minimum harmonic mean distance, D=fix dispersion, Sk=skewness of range, K=kurtosis of range, Sp=spread of range

Table 1

| Nest[a] Area | Sex | OTA | N | Home Range Shape: Maximum Polygon width | Harmonic Mean Hr | D | Sk | K | Sp | Use of OTA: Number inside: OTA | % | Range Rd | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BrcsD | Male | y | 88 | 27580 | 1040.8 | 5.5 | 23.3 | 15.4 | 2891 | 36 | 40.9 | 19 | 22.0 |
| Cabin | Female | y | 69 | 33680 | 3533.0 | 2.5 | 2.7 | 4.3 | 5966 | 51 | 73.9 | 31 | 45.0 |
| Bitch | Male | n | 113 | 23260 | 1166.3 | 4.9 | 4.6 | 12.9 | 3041 | 17 | 15.0 | 1 | 0.8 |
| PrUp | Male | n | 89 | 24420 | 1235.4 | 3.6 | 4.3 | 9.3 | 3170 | 16 | 18.0 | 1 | 1.0 |
| CSJ | Male | y | 48 | 28060 | 2455.2 | 3.3 | 11.7 | 6.2 | 4664 | 28 | 58.3 | 15 | 31.0 |
| WHSW | Male | y | 47 | 40440 | 2060.8 | 3.5 | 15.2 | 8.3 | 4920 | 28 | 59.6 | 9 | 19.0 |
| BPtUp | Female | n | 59 | 20370 | 2235.0 | 1.7 | 2.2 | 2.7 | 3621 | 22 | 37.3 | 0 | 0.0 |
| Beech | Male | n | 95 | 35920 | 1463.5 | 2.2 | 1.2 | 4.5 | 2937 | 15 | 15.8 | 2 | 2.0 |
| HHGS | Male | n | 86 | 9263 | 722.6 | 2.6 | 2.2 | 5.4 | 1511 | 0 | 0.0 | 0 | 0.0 |
| WHNE | Female | y | 60 | 20100 | 1044.6 | 3.1 | 21.5 | 8.6 | 2945 | 22 | 36.7 | 2 | 3.0 |
| CGG | Male | n | 77 | 15000 | 2060.7 | 1.3 | 1.0 | 2.0 | 3142 | 4 | 5.2 | 0 | 0.0 |
| PlMir | Male[b] | y | 63 | 24000 | 62.4 | 7.8 | 949.0 | 148.5 | 1188 | 41 | 65.1 | 9 | 14.0 |
| Fang | Female[b] | n | 46 | 17360 | 1393.5 | 1.8 | 1.6 | 2.6 | 2052 | 2 | 4.3 | 0 | 0.0 |
| PChm | Female | n | 42 | 10620 | 392.4 | 2.7 | 9.1 | 9.1 | 1319 | 0 | 0.0 | 0 | 0.0 |
| OgRdD | Female[b] | n | 41 | 28750 | 2087.6 | 2.6 | 3.0 | 4.2 | 3395 | 0 | 0.0 | 0 | 0.0 |
| MGUp | Female | n | 38 | 13560 | 2475.8 | 1.5 | 2.0 | 2.3 | 3925 | 3 | 7.9 | 0 | 0.0 |
| PrR1 | Female[b] | n | 34 | 10190 | 1300.9 | 1.0 | 0.8 | 1.6 | 2068 | 3 | 8.8 | 0 | 0.0 |
| TomBW | Female | n | 34 | 28740 | 3202.3 | 2.4 | 3.4 | 4.7 | 6292 | 16 | 47.1 | 1 | 3.0 |
| FvrB | Female | n | 30 | 13710 | 1280.3 | 3.4 | 15.3 | 8.3 | 3171 | 12 | 40.0 | 0 | 0.0 |
| Sw1D | Female | n | 29 | 22830 | 3236.5 | 1.9 | 3.6 | 3.2 | 5557 | 9 | 31.0 | 1 | 3.0 |
| BBGE | Female | n | 23 | 15000 | 1518.6 | 1.8 | 2.6 | 3.4 | 2934 | 1 | 4.3 | 0 | 0.0 |
| BBH | Female | n | 21 | 21550 | 2058.2 | 1.1 | 1.0 | 1.9 | 3474 | 6 | 28.6 | 1 | 5.0 |
| BBPl | Female[b] | n | 17 | 32090 | 3079.6 | 1.9 | 1.2 | 3.0 | 4888 | 5 | 29.4 | 1 | 0.0 |
| FwnHb | Male | y | 11 | 16090 | 2570.7 | 1.6 | 2.0 | 2.9 | 4577 | 6 | 54.5 | 3 | 27.0 |
| Tick3 | Female[b] | n | 11 | 12770 | 500.9 | 1.6 | 5.0 | 3.9 | 1235 | 2 | 18.2 | 0 | 0.0 |

[a] Nesting areas are abreviated as follows: BrcsD-Beercase Draw, PrUp-Priest Upper, WHSW-Wildhorse SW, BPtUp-Balls Pt Upstream, Beech-Beecham, HHGS-Hell Hole Gaging Station, WHNE-Wildhorse Butte NE, CGG-Cattleguard Gate, PlMir-Powerline Mirror, PChm-Peregrine Chimney, OgRD-Ogden Rock Downstream, MGUp-Mother Giant Upstream, PrR1-Priest Rapids I, TomBW-Tom Butte West FvrB-Fever Basin, Sw1D-Swan I Draw, BBGE-Balls Basin GE, BBH-Balls Basin Hamer, FwnHb-Fawn Humpback, Tick3-Tick III. Falcons from Priest Rapids II, Wildhorse Face Fenceline, and Henderson Draw are not listed due to transmitter difficulties and resulting lack of data.

[b] Nest attempt failed or not initiated; no information for nest location is listed for birds that did not initiate a scrape OTA: y=OTA shadow, n=west of OTA N=Number of fixes with error ellipses <1000 ha Hc=Harmonic Mean center, Ac=Arithmatic center Harmonic mean: Hr=minimum harmonic mean distance, D=fix dispersion, Sk=skewness of range, K=kurtosis of range, Sp=spread of range

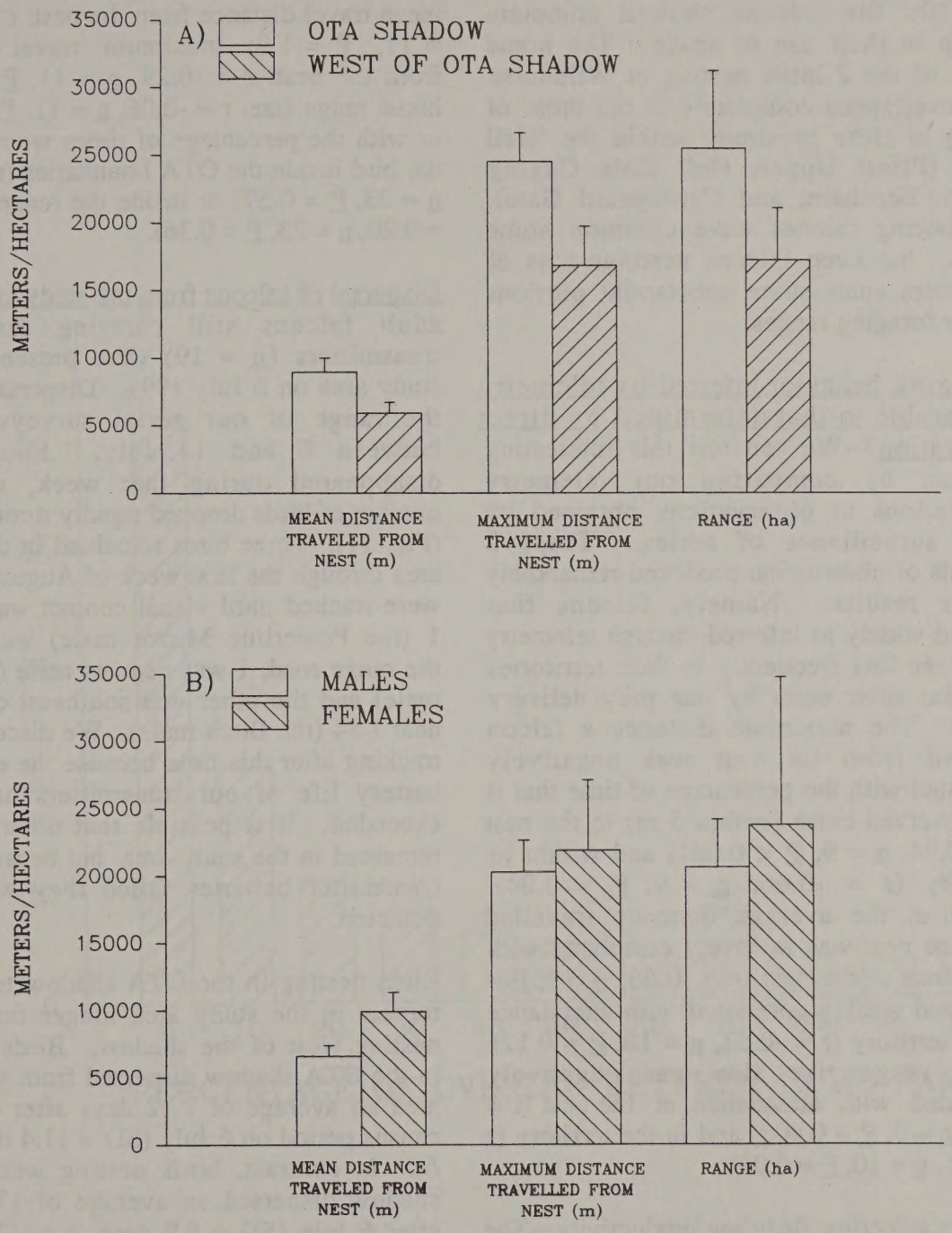



Fig. 9. Ranging habits of 12 radio-tagged prairie falcons. Distances and areas traveled are contrasted with respect to the aerie location (in the OTA shadow versus west of the shadow) and sex. Home range in ha are the 95% core areas around the harmonic mean. Averages + 1 SE are plotted.

of the study area), but the remaining 80 pairs overlapped each other by an average of 40% (Fig. 10). Six falcons showed complete overlap in their use of space. The home ranges of the 2 birds nesting at Wildhorse Butte overlapped completely as did those of nesting in close proximity within the "Hell Hole" (Priest Upper, Hell Hole Gaging Station, Beecham, and Cattleguard Gate). Neighboring falcons have common home ranges, but even falcons nestings tens of kilometers apart share substantial portions of their foraging ranges.

Is ranging behavior inferred by telemetry comparable to that determined by direct observation?--We can test this interesting question by comparing our telemetry observations to observations obtained by direct surveillance of aeries. These 2 methods of observation produced remarkably similar results. Namely, falcons that traveled widely as inferred through telemetry were seen less frequently in their territories and near their nests by our prey delivery teams. The maximum distance a falcon traveled from its nest was negatively correlated with the percentage of time that it was observed close (within 5 m) to the nest ($r = -0.94$, $n = 9$, $P < 0.001$) and within its territory ($r = -0.66$, $n = 9$, $P = 0.04$). Likewise, the average distance travelled from the nest was inversely correlated with attendance at the nest ($r = -0.66$, $n = 9$, $P = 0.05$) and weakly correlated with attendance in the territory ($r = -0.52$, $n = 10$, $P = 0.12$). Home range size also was negatively correlated with attendance at the nest ($r = -0.84$, $n = 9$, $P = 0.005$) and in the territory ($r = -0.65$, $n = 10$, $P = 0.04$).

Factors affecting fledgling productivity.--The majority of radio-tagged falcons successfully fledged young (73% of 26 pairs; the fate of 1 pair was unknown). However, the number of young fledged per pair varied substantially (from 0 - 5). This variation was not significantly correlated with a bird's ranging habits (correlating number of fledglings with: mean travel distance from the nest: $r = 0.0$, $n = 11$, $P = 1.0$; maximum travel distance from the nest: $r = -0.29$, $n = 11$, $P = 0.38$; home range size: $r = -0.06$, $n = 11$, $P = 0.85$) or with the percentage of times we recorded the bird inside the OTA boundaries ($r = 0.13$, $n = 23$, $P = 0.57$) or inside the range road ($r = 0.20$, $n = 23$, $P = 0.36$).

Dispersal of falcons from the study area.--All adult falcons still carrying functional transmitters ($n = 19$) were present in the study area on 6 July 1991. Dispersal out of the range of our aerial surveys began between 6 and 13 July. Four birds disappeared during that week, and the number of birds dropped rapidly through July (Fig. 11). Three birds remained in the study area through the first week of August. All 3 were tracked until visual contact was made; 1 (the Powerline Mirror male) was inside the range road, 1 was near its aerie (the CSJ male) and the other was southeast of Boise near I-84 (the Bitch male). We discontinued tracking after this time because the expected battery life of our transmitters had been exceeded. It is possible that other falcons remained in the study area, but because their transmitter batteries failed they were not detected.

Birds nesting in the OTA shadow tended to remain in the study area longer than birds nesting west of the shadow. Birds nesting in the OTA shadow dispersed from the study area an average of 27.2 days after our first census period on 6 July (SD = 11.4 days, $n = 6$). In contrast, birds nesting west of the shadow dispersed an average of 17.9 days after 6 July (SD = 8.9 days, $n = 13$). This difference approached significance ($F_{1,17} = 3.7$, $P = 0.07$). Hatch date and success were not correlated with dispersal date (correlation with hatch date: $r = 0.15$, $n = 16$, $F = 0.59$; 1-way ANOVA comparing 14

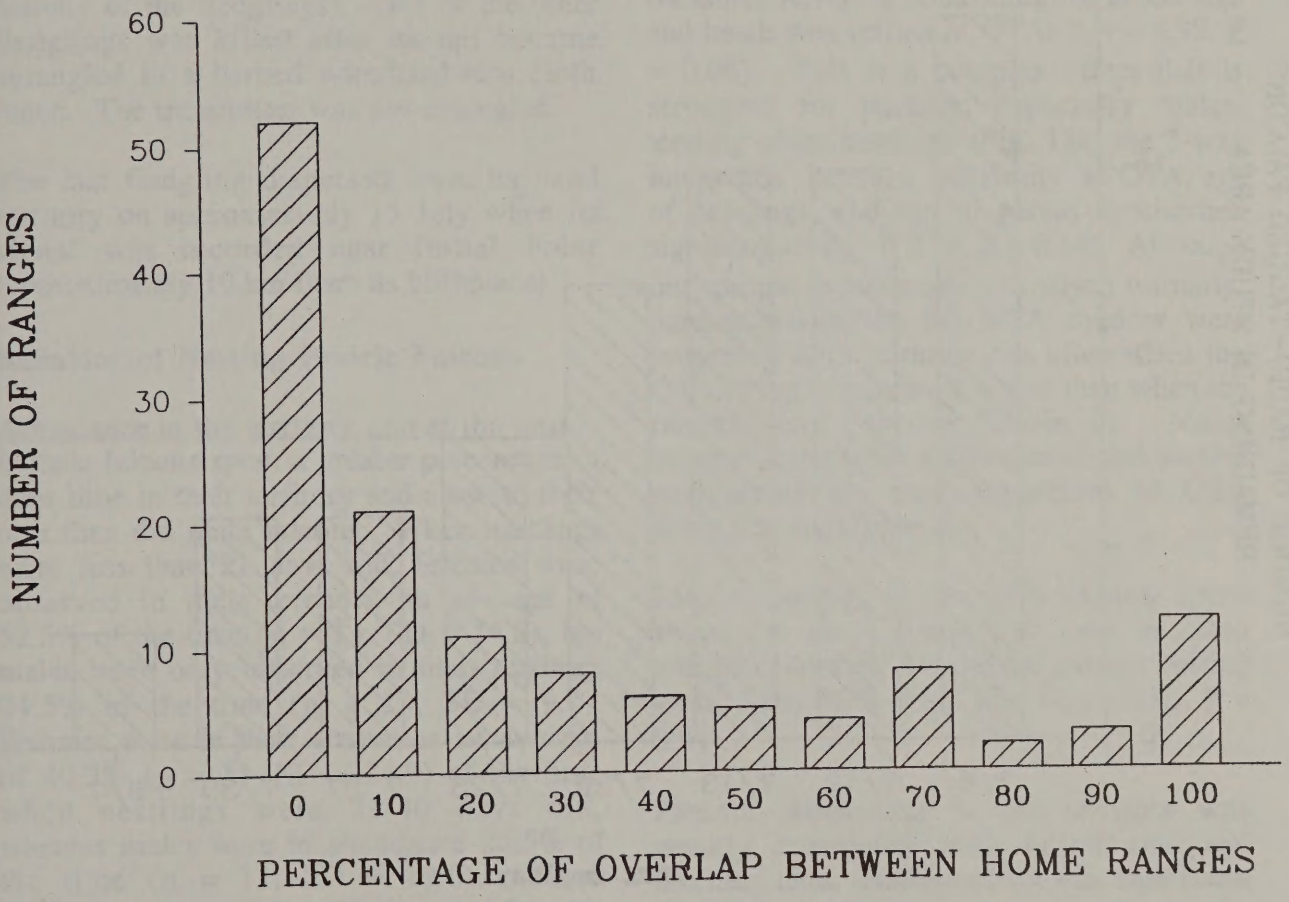



Fig. 10. Overlap between home ranges (95% core areas around harmonic means) of 12 prairie falcons (see text for determination of overlap).

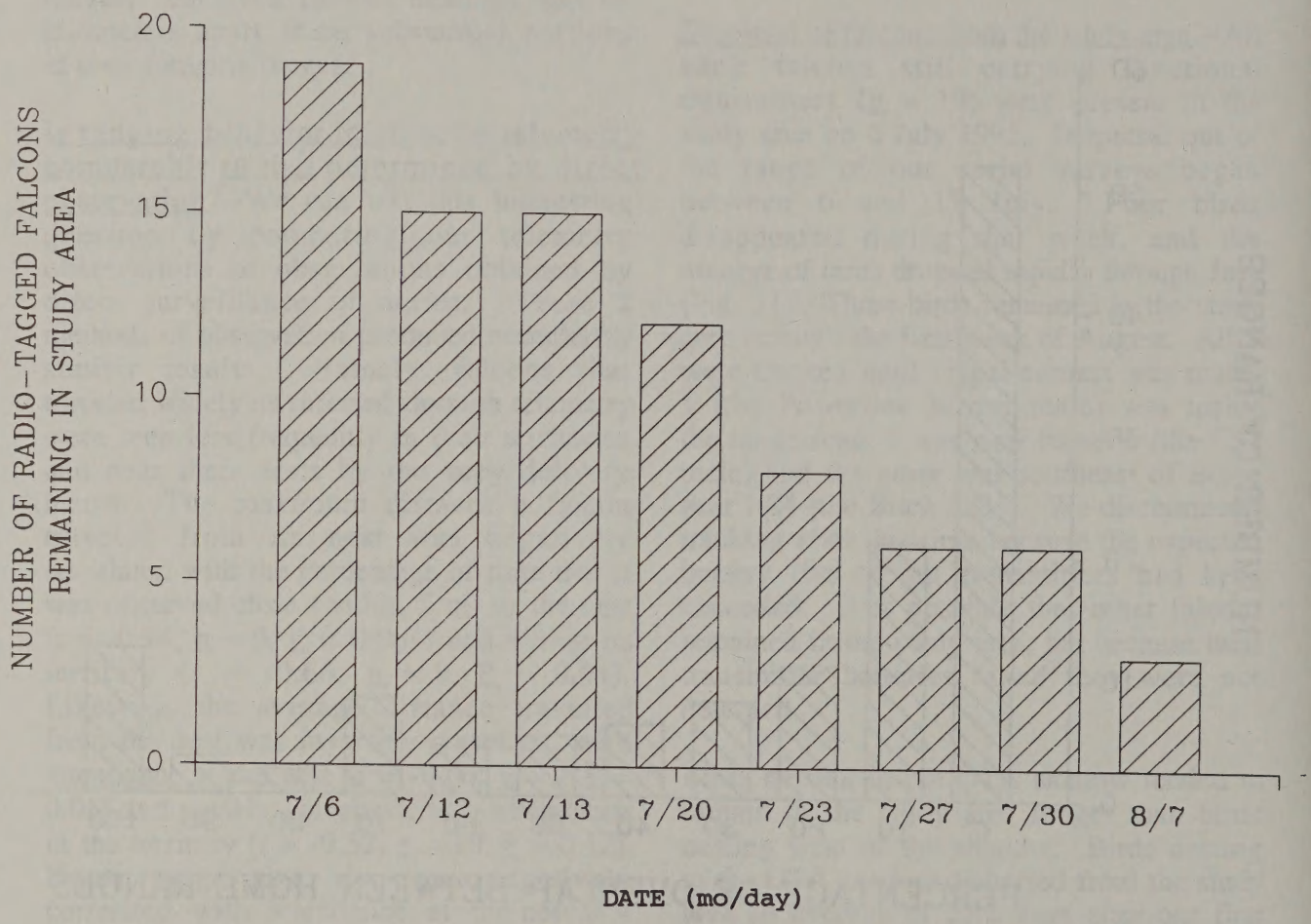



Fig. 11. Dispersal of radio-tagged falcons from the study area. We censused falcons from aircraft on days listed and recorded their presence or absence from the study area.

successful and 3 unsuccessful sites: $F_{1,15}$ = 0.38, P = 0.55).

Movements of radio-tagged fledglings.--All 6 nestlings fitted with tarsal transmitters fledged from their aeries. They behaved normally while in the scrape, paying little attention to their transmitters. Four transmitters failed shortly after nestlings fledged (these failures were due to poor quality crystals and were unlikely related to the activity of the fledglings). One of the other fledglings was killed after its tail became entangled in a barbed wire/hardware cloth fence. The transmitter was not entangled.

The last fledgling dispersed from its natal territory on approximately 15 July when its signal was recorded near Initial Point (approximately 10 km from its birthplace).

**Behavior of Nesting Prairie Falcons**

Attendance in the territory and at the nest.--Female falcons spent a greater percentage of their time in their territory and close to their nest than did male falcons. When nestlings were less than 21 days old, females were observed in their territory an average of 52.5% of the time (n = 13, SD = 14.8), but males were only observed in their territory 24.5% of the time (n = 13, SD = 9.0). Females were in their territories an average of 40.3% (n = 11, SD = 24.9) of the time when nestlings were 21-40 days old, whereas males were in attendance 26.5% of the time (n = 11, SD = 19.0). When nestlings were less than 21 days old females were seen within 5 m of the aerie 36.9% of the time (n = 14, SD = 18.4), and males were seen near the nest 10.2% of the time (n = 14, SD = 8.7). Both sexes reduced the time they spent at the nest as nestlings aged, but females still spent a greater percentage of their time at the nest than did males (nestlings 21-40 days old: percentage of time female at nest = 8.7%, n = 12, SD = 11.6; for male = 4.1%, n = 12, SD = 7.4).

Parental attendance in the territory might be influenced by the proximity of the aerie to the OTA. Parents that nested within the OTA shadow spent, on average, only 1/2 - 1/3 as much time in their territories as parents that nested west of the OTA (Fig. 12a). This trend approached significance in a repeated measures ANOVA controlling for brood size and hatch date (effect of OTA: $F_{1,7}$ = 4.38, P = 0.08). This is a complex effect that is strongest for parents, especially males, tending older nestlings (Fig. 12a; the 3-way interaction between proximity to OTA, age of nestlings, and sex of parent approached significance: $F_{1,7}$ = 2.79, P = 0.14). Although our sample is too small to analyze formally, parents nesting in the OTA shadow were present in their territory less often when the OTA firing ranges were active than when the ranges were inactive (Table 2). Males outside of the OTA shadow exhibited similar nest attendance rates regardless of OTA firing activity (Table 2).

Falcons nesting in the OTA shadow spent about the same amount of time in close proximity to their nest as did parents nesting west of the OTA (Fig. 12b; $F_{1,8}$ = 0.01, P = 0.91).

Parental attendance in the territory was weakly correlated with brood size and hatching data. Neither effect was significant in standard correlation analyses (Table 3). However, hatch date was a significant covariate in the repeated measures ANOVA testing for the effects of nestling age, sex of parent, and proximity to the OTA ($F_{1,8}$ = 7.9, P = 0.02). Parents of the late hatching nests were less attentive than those at nests that hatched early in the year.

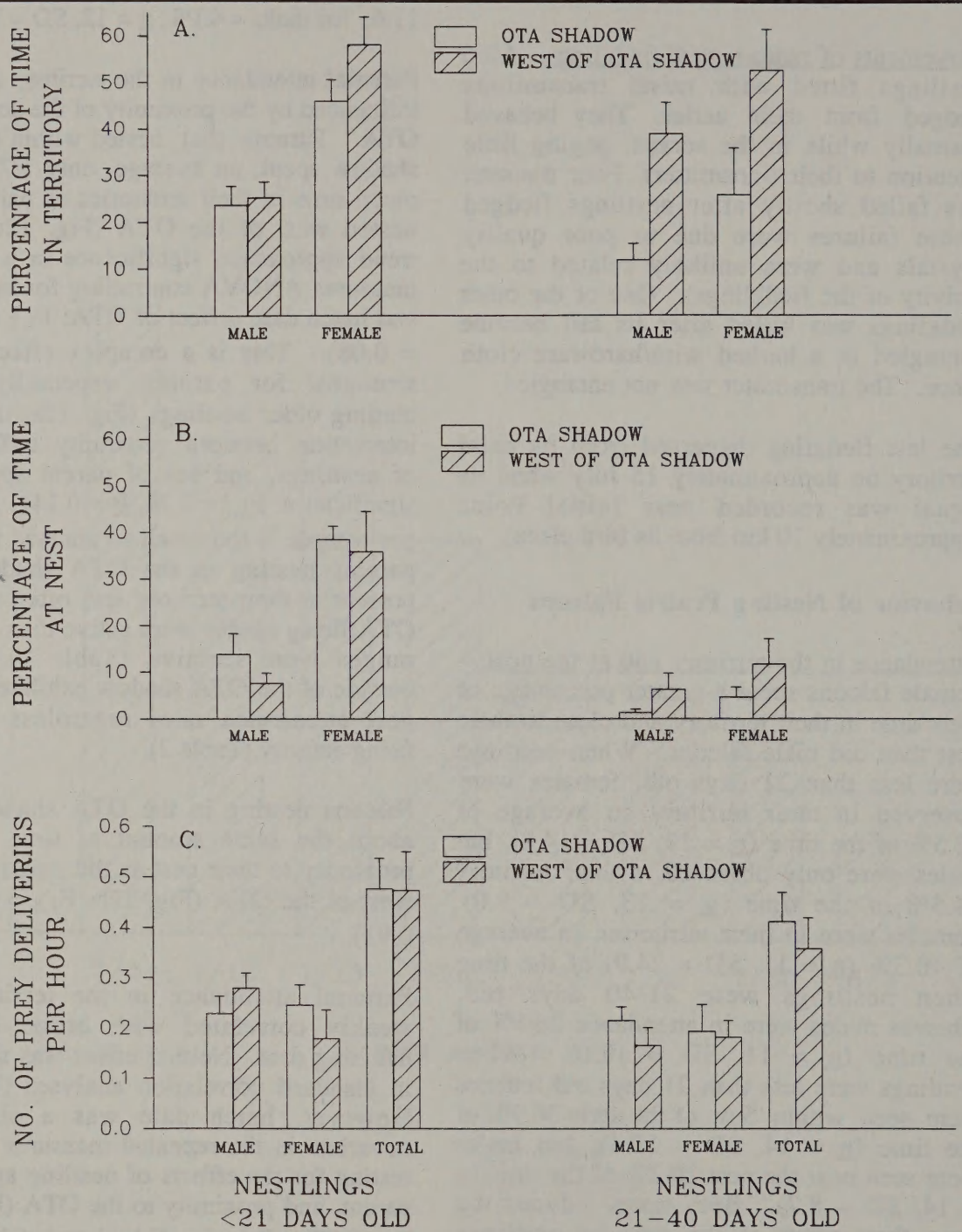



Fig. 12. Behavior of parental prairie falcons nesting in the OTA shadow relative to those nesting west of the shadow. Average behaviors (+ 1 SE) are presented separately for parents tending nestlings < 21 days old and those tending 21-40 day old nestlings.

Table 2. Behavior at prairie falcon aeries on days when the OTA training ranges were active compared to days when they were not active.

| | Time (%) in Territory | | Time (%) at Nest | | Prey Deliveries/hr | | |
|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Total |
| OTA Shadow | | | | | | | |
| Range N | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Active X | 8.0 | 8.9 | 2.1 | 3.0 | 0.30 | 0.20 | 0.50 |
| SD | 7.4 | 7.6 | 3.4 | 2.5 | 0.15 | 0.23 | 0.18 |
| Ranges N | 3 | 3 | 4 | 4 | 4 | 4 | 4 |
| Inactive X | 14.4 | 12.2 | 1.4 | 3.6 | 0.16 | 0.19 | 0.35 |
| SD | 9.8 | 3.6 | 2.4 | 2.7 | 0. 04 | 0.14 | 0.14 |
| West of OTA | | | | | | | |
| Ranges N | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Active X | 32.3 | 42.8 | 0.13 | 1.0 | 0.22 | 0.16 | 0.42 |
| SD | 18.3 | 3.0 | 0.11 | 0.17 | 0.22 | 0.05 | 0.12 |
| Ranges N | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Inactive X | 28.6 | 52.6 | 0.17 | 1.7 | 0.15 | 0.06 | 0.21 |
| SD | 4.6 | 2.8 | 0.20 | 0.73 | 0.14 | 0.001 | 0.14 |

Parents spent less time in the territory and at their nests as nestlings aged. Correlation analyses using each day of observation as an independent sample of behavior reveal a striking difference in these relationships depending on the proximity of the territory to the OTA (Table 4). Parents tending nests in the OTA shadow showed strong reductions in attendance as nestlings aged, but parents tending nests outside of the OTA shadow showed weak, nonsignificant declines in attendance.

Attendance in the territory might influence fledging success. The number of fledglings produced might increase with the amount of time parents spent in the territory. Although this trend is not quite significant ($r = 0.61$, $n = 10$, $P = 0.08$), it is striking given the fact that parents with many fledglings would be expected to spend less time in the territory in order to procure food for their large broods. Attendance within 5 m of the nest was not related to the production of fledglings ($r = 0.34$, $n = 9$, $P = 0.41$).

Delivery of prey items to the nestlings.--Males and females delivered prey items to nestlings with nearly equal frequency, and this was independent of the proximity of the nest to the OTA (Fig. 12c; $F_{1,10} = 0.04$, $P = 0.85$). The 3-way interaction between nestling age, proximity to the OTA, and sex of the parent approached significance ($F_{1,10} = 3.3$, $P = 0.10$) because males west of the OTA and females in the OTA shadow tended to reduce their prey delivery rates as nestlings aged, but males in the OTA and females west of the OTA did not. Prey delivery rates at nests in the OTA shadow and west of the OTA tended to be highest when the OTA firing ranges were active (Table 2). Females retrieved prey from caches more often than males but this was

Table 3. Pearson correlations between brood size, hatching date, and parental behavior at all nests. Percentages were transformed prior to analysis (arcsine of square root).

| Parental Behavior | Brood Size r | N | P | Hatching Date r | N | P |
|---|---|---|---|---|---|---|
| Percentage of Time in Territory | | | | | | |
| male (nestlings < 20 days old) | 0.22 | (13) | 0.48 | -0.18 | (13) | 0.56 |
| male (nestlings 21-40 days old) | 0.09 | (11) | 0.80 | -0.31 | (11) | 0.36 |
| female (nestlings < 20 days old) | -0.01 | (13) | 0.97 | -0.23 | (13) | 0.44 |
| female (nestlings 21-40 days old) | -0.06 | (11) | 0.87 | -0.30 | (11) | 0.36 |
| Percentage of Time at Nest | | | | | | |
| male (nestlings < 20 days old) | 0.31 | (14) | 0.29 | -0.50 | (14) | 0.11 |
| male (nestlings 21-40 days old) | 0.47 | (12) | 0.13 | -0.72 | (12) | <0.01 |
| female (nestling < 20 days old) | 0.42 | (14) | 0.13 | 0.07 | (14) | 0.39 |
| female (nestlings 21-40 days old) | 0.51 | (12) | 0.09 | -0.79 | (12) | <0.01 |
| Prey Deliveries per Hr | | | | | | |
| male (nestlings < 20 days old) | 0.33 | (14) | 0.24 | -0.47 | (14) | 0.09 |
| male (nestlings 21-40 days old) | 0.44 | (14) | 0.12 | -0.11 | (14) | 0.71 |
| female (nestlings < 20 days old) | 0.66 | (14) | 0.01 | -0.71 | (14) | <0.01 |
| female (nestlings 21-40 days old) | 0.67 | (14) | <0.01 | -0.60 | (14) | 0.02 |
| total (nestlings < 20 days old) | 0.69 | (14) | <0.01 | -0.75 | (14) | <0.01 |
| total (nestlings 21-40 days old) | 0.76 | (14) | <0.01 | -0.54 | (14) | 0.05 |

Table 4. Pearson correlations between age of nestlings (days) and parental behavior at nests inside the OTA Shadow and west of the OTA Shadow.

| Parental Behavior | Nestling Age (OTA nests) r | N | P | Nestling Age (West of OTA nests) r | N | P |
|---|---|---|---|---|---|---|
| Time (%) in Territory | | | | | | |
| Male | -0.75 | (37) | <0.001 | 0.23 | (23) | 0.29 |
| Female | 0.73 | (37) | <0.001 | 0.00 | (23) | 1.0 |
| Time (%) at Nest | | | | | | |
| Male | -0.84 | (37) | <0.001 | -0.34 | (25) | 0.10 |
| Female | -0.93 | (37) | <0.001 | -0.38 | (25) | 0.07 |
| Prey Deliveries/hr | | | | | | |
| Male | 0.18 | (42) | 0.24 | -0.41 | (25) | 0.05 |
| Female | 0.36 | (42) | 0.02 | -0.09 | (25) | 0.68 |
| Total | 0.42 | (42) | 0.005 | -0.28 | (25) | 0.18 |

primarily confined to the early nestling stage. We witnessed 13 instances of birds delivering previously cached food items to their nestlings. Twelve retrievals occurred when nestlings were < 21 days old, 10 of which were by females. The only retrieval when nestlings were 21-40 days old was by a female. We observed 8 other possible retrievals, and females were involved in 7 of these (4 when nestlings were < 21 days old).

Delivery rate of prey to nestlings by females was strongly correlated with brood size. Females tending large broods fed them more frequently than females tending small broods (Table 3). Males tended to increase their delivery rates as brood size increased, but this was not significant (Table 3). The total number of prey items delivered to nests mirrored female rates; it increased as brood size increased (Table 3). Brood size was a significant covariate in our repeated measures ANOVA for males and females ($F_{1,10} = 6.01$, $\underline{P} = 0.03$).

Hatching date was strongly correlated with the prey delivery rates of females; delivery rates declined as hatching date became later (Table 3). Male delivery rates were less responsive to hatch date. Total delivery rates declined sharply as hatch date increased (Table 3), but hatch date was less important than brood size, and it was not a significant covariate in our ANOVA using both male and female prey delivery rates ($F_{1,10} = 1.5$, $\underline{P} = 0.24$).

We conducted a separate repeated measures ANOVA to determine the influence of proximity to OTA, brood size, and hatch date on the <u>total</u> number of prey items delivered to nests per hr (those delivered by males, females, and birds of unknown sex). The results mirror those found in the male/female analyses; proximity to the OTA did not influence the rate at which parents provisioned their nestlings ($F_{1,10} = 0.36$, $\underline{P} = 0.59$), brood size had a strong effect on prey delivery rate ($F_{1,10} = 8.27$, $\underline{P} = 0.02$), and hatch date had no effect on total delivery rate ($F_{1,10} = 1.43$, $\underline{P} = 0.26$).

Most prey items delivered to nestlings were mammals, notably Townsend's ground squirrels. Forty-seven percent of 162 prey items brought to nests west of the OTA shadow were Townsend's ground squirrels as were 41% of 207 items delivered to nestlings within the OTA shadow (Fig. 13). Falcons nesting within the OTA shadow delivered fewer Townsend's ground squirrels and more kangaroo rats, birds, and reptiles to their nestlings than falcons nesting west of the OTA. However, the distribution of prey items brought to nests in the OTA shadow was not quite significantly different from the distribution of items brought to nests west of the OTA shadow (likelihood ratio test on categories in Fig. 13 lumping birds and reptiles: $G^2_{(4)} = 8.6$, $\underline{P} = 0.07$).

We observed 3 instances of falcons delivering insects (presumably grasshoppers) to their nestlings. All observations occurred at nests west of the OTA shadow from 20-28 June. Two males and 1 female were observed to deliver from 2 to 75 insects in a single day, as also noted by Holthuijzen et al. (1987).

Delivery rates varied throughout the day. Few deliveries were made early in the morning or late in the evening. Instead, rates peaked in mid-morning and again in late afternoon, with a midday lull (Fig. 14). The distribution of deliveries throughout the day did not differ between OTA sites and sites west of the OTA shadow (likelihood ratio test on categories in Fig. 14 lumping 0 - 1 hr after sunrise and 14 - 15 hr after sunrise: $G^2_{(13)} = 9.4$, $\underline{P} = 0.74$).

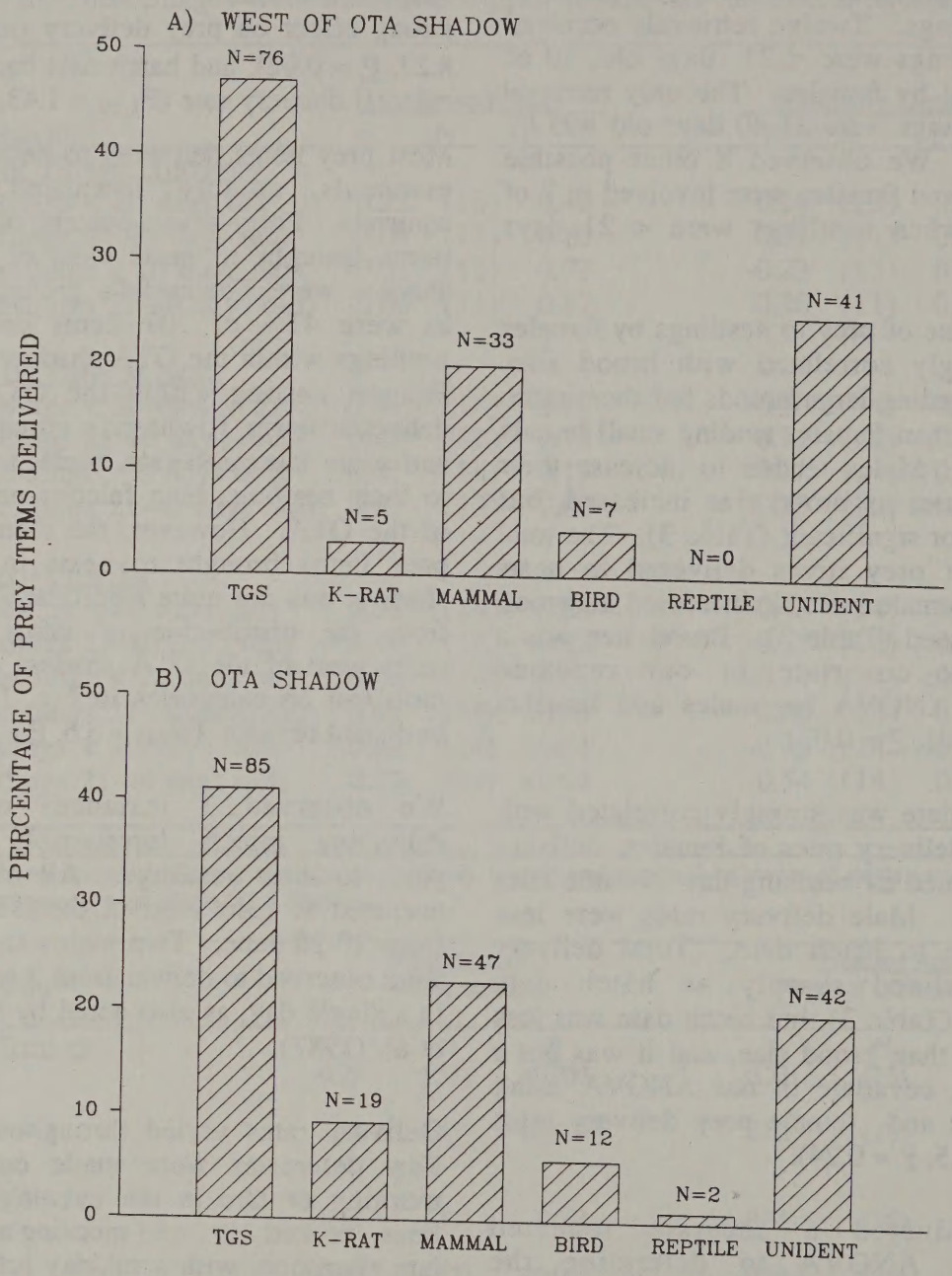



Fig. 13. Composition of prey items delivered to nestling prairie falcons in the OTA shadow compared to west of the shadow. Percentages are plotted and corresponding numbers of each prey type are given above each bar. TGS = Townsend's ground squirrel, K-rat = kangaroo rat, Mammal = unidentified mammal, Unident = unidentified prey item. Insect prey items are not included.

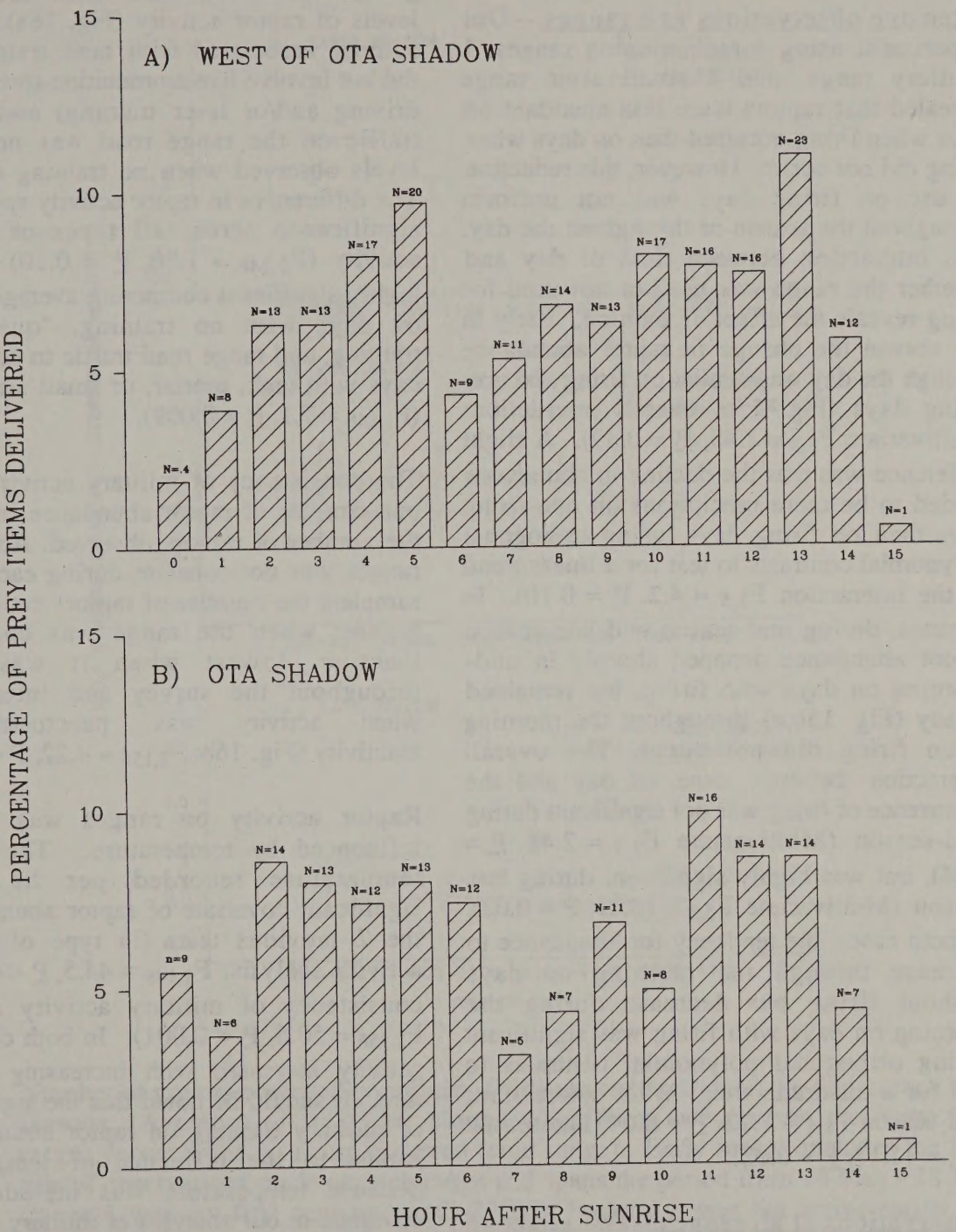



Fig. 14. Timing of prey deliveries at nests west of the OTA shadow compared to nests within the shadow. Percentages are plotted and absolute number of deliveries/hr are listed above bars.

**Military Training and Raptor Abundance**

Intensive observations at 6 ranges.--Our experiment using 4 tank training ranges, 1 artillery range, and 1 small arms range revealed that raptors were less abundant on days when firing occurred than on days when firing did not occur. However, this reduction in use on firing days was not uniform throughout the season or throughout the day. The interaction between time of day and whether the range was used or not used for firing reveals the effect of training. Early in the season the change in raptor abundance through the day was similar on firing and non-firing days (Fig. 15a; overall interaction: Multivariate $F_{3,3} = 1.43$, $P = 0.39$). A slight difference was that the decline in abundance tended to be more precipitous on non-firing days than on firing days (using orthogonal polynomial contrasts to test for a linear trend in the interaction $F_{1,5} = 4.2$, $P = 0.10$). In contrast, during mid-season and late season raptor abundance dropped sharply in mid-morning on days with firing, but remained steady (Fig. 15b,c) throughout the morning when firing did not occur. The overall interaction between time of day and the occurrence of firing was not significant during mid-season (Multivariate $F_{3,3} = 2.48$, $P = 0.24$), but was highly significant during late season (Multivariate $F_{3,3} = 18.22$, $P = 0.02$). In both cases, the tendency for abundance to increase through the morning on days without firing but decrease during the morning on days with firing was significant (using orthogonal polynomial contrasts to test for a quadratic trend in the interaction: mid-season $F_{1,5} = 7.12$, $P = 0.04$; late season $F_{1,5} = 11.17$, $P = 0.02$).

Observations at all ranges.--The effect of training also was evident in our wider sample of 11 ranges (Fig. 16). However, all military activity was not equally disruptive to raptors. Artillery training, small arms training, and tank training that involved firing (the main turret guns and/or the machine guns) were associated with the lowest levels of raptor activity (Fig. 16a). Raptor activity associated with tank training that did not involve live ammunition (preparation, driving and/or laser training) and convoy traffic on the range road was not below levels observed when no training occurred. The differences in raptor activity approached significance across all types of military activity ($F_{5,148} = 1.86$, $P = 0.10$) and was highly significant comparing average activity on days with no training, "quiet" tank training, and range road traffic to activity on days with tank, mortar, or small arms firing ($F_{1,148} = 7.1$, $P = 0.009$).

The consistency of military activity during our samples of raptor abundance influenced the number of raptors observed. Activity on ranges was not constant during each of our samples; the number of raptors counted was highest when the range was completely inactive, lowest when it was active throughout the survey and intermediate when activity was punctuated with inactivity (Fig. 16b; $F_{2,156} = 4.22$, $P = 0.02$).

Raptor activity on ranges was strongly influenced by temperature. The average temperature recorded per hr was a significant covariate of raptor abundance in the 2 previous tests (in type of military activity analysis: $F_{1,148} = 44.5$, $P < 0.001$; in consistency of military activity analysis: $F_{1,156} = 50.6$, $P < 0.001$). In both cases bird activity increased with increasing temperature. It should be noted that the significance of military training on raptor abundance is robust to the influence of temperature, because temperature was included as a covariate in our analyses of military effects.

Military training and raptor behavior.--The 4 major groups of raptors utilizing the training ranges exhibited species-typical repertoires of behavior. Northern harriers spent more

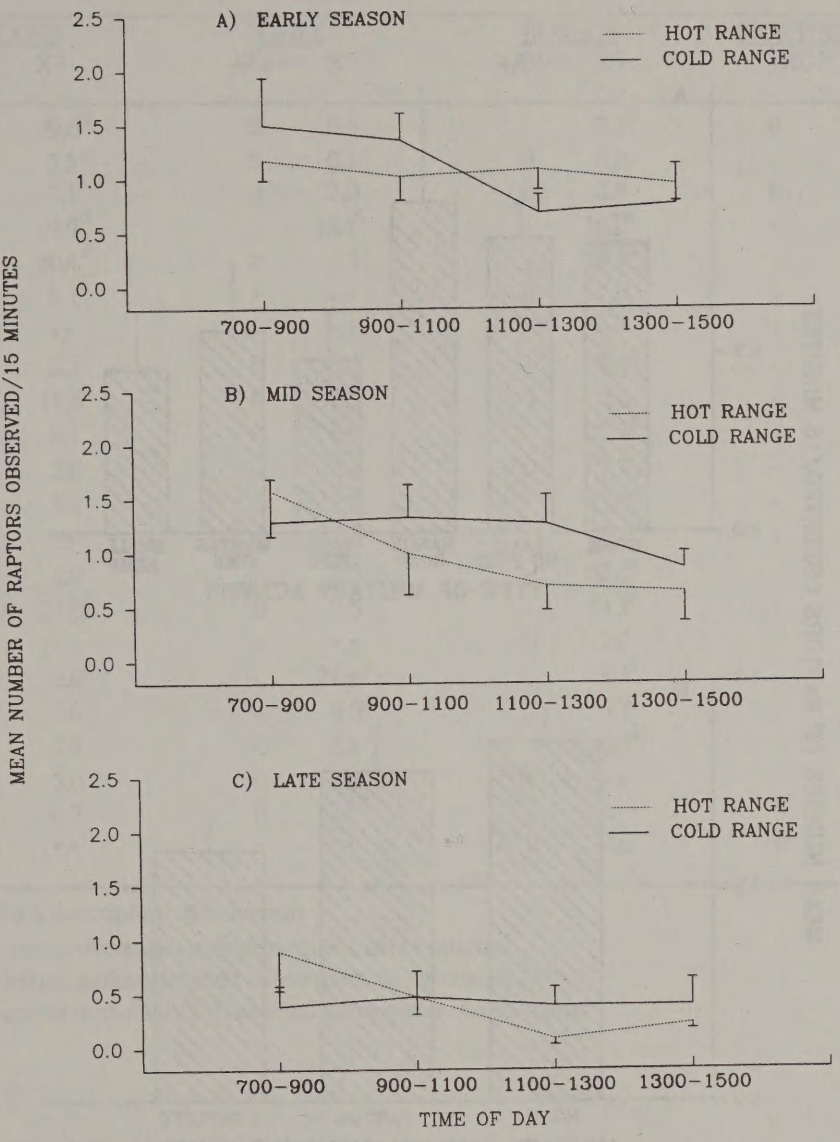



Fig. 15. Number of raptors observed on military firing ranges throughout the day in each of 3 seasons. Averages +/- 1 SE are plotted when firing occurred on the range (hot range) versus when no firing occurred (cold range). Early season includes the first pair of observations made on each range and spans the period from 16 May - 18 July (range 1 was not first censused until 22 July because it was not active earlier, all other ranges were censused from 16 May - 18 June). Mid season includes the second pair of observations made on each range and spans the period from 31 May - 26 July. Late season includes the third pair of observations made on each range and spans the period from 6 July - 8 August.

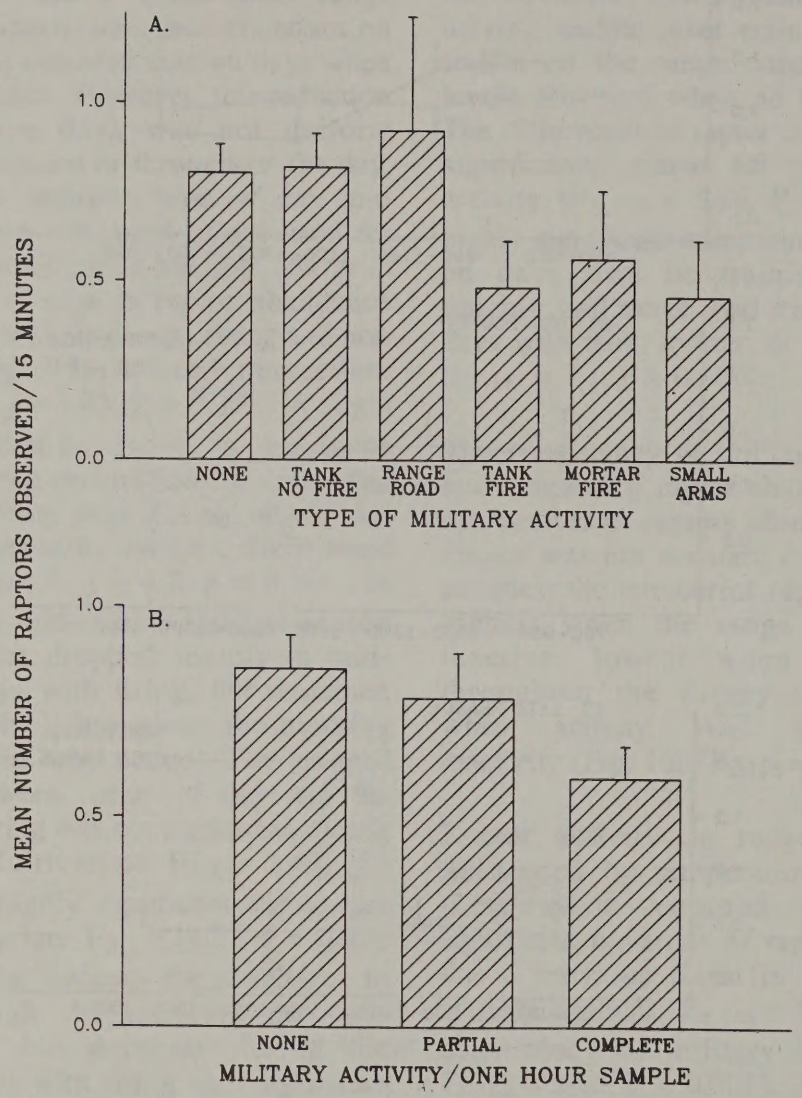



Fig. 16. Average number of raptors (+ 1 SE) observed on military firing ranges under different firing regimes. Type of military activity on the range (A) was categorized as: none = no activity; Tank/no fire = driving, preparing, laser-training tanks; range road = convoy traffic on the range road; tank/fire = tanks shooting main turret gun and/or machine guns; mortar fire = artillery firing; and small arms = M-60, M-16, M-40 rifle and 45 pistol firing. Military activity per hr (B) was categorized as: none = no activity, partial = activity punctuated by periods of inactivity, and complete = sustained activity during entire hr.

Table 5. Comparison of behavioral repertoires defined by initial versus subsequent observations. Results are from McNemar's test comparing the proportions of each behavior found in initial versus subsequent samples.

| | FALCONS | | OWLS | | BUTEOS | | NORTHERN HARRIERS | |
|---|---|---|---|---|---|---|---|---|
| ACT[a] | +/0/-[b] | $X^2$ | +/0/-[b] | $X^2$ | +/0/-[b] | $X^2$ | +/0/-[b] | $X^2$ |
| FL1 | - | 19.6[e] | 0 | 0.5 | - | 7.5[d] | 0 | 3.6 |
| FL2 | - | 5.5[c] | 0 | 0.1 | 0 | 0.8 | - | 7.0[d] |
| FL3 | 0 | 0.1 | 0 | 2.0 | 0 | 0.8 | 0 | 1.6 |
| GL1 | - | 9.9[d] | - | 15.1[e] | - | 16.2[e] | - | 52.5[e] |
| GL2 | - | 10.4[d] | 0 | 3.3 | - | 19.9[e] | - | 7.7[e] |
| GL3 | - | 8.1[d] | • | •.• | 0 | 2.9 | + | 5.2[c] |
| QU1 | • | •.• | • | •.• | • | •.• | - | 85.6[e] |
| SO1 | 0 | 3.7 | 0 | 2.0 | - | 8.4[d] | - | 8.4[d] |
| SO2 | - | 11.6[e] | 0 | 2.5 | 0 | 0.0 | - | 9.4[d] |
| SO3 | - | 8.1[d] | • | •.• | - | 22.9[e] | - | 8.1[d] |
| HO1 | 0 | 2.0 | 0 | 3.3 | 0 | 3.3 | - | 6.2[c] |
| HO2 | - | 5.2[c] | 0 | 2.0 | - | 13.3[e] | • | •.• |
| HO3 | • | •.• | 0 | 2.0 | - | 4.3[c] | • | •.• |
| DV | 0 | 1.0 | 0 | 3.3 | - | 62.1[e] | - | 10.1[d] |
| AT | - | 11.3[e] | 0 | 2.5 | - | 14.1[e] | - | 25.0 |
| CP | • | •.• | • | •.• | 0 | 2.0 | - | 5.8[c] |
| PE | - | 6.6[c] | - | 21.8[e] | - | 8.1[d] | - | 57.3[e] |
| MA | 0 | 2.0 | - | 4.3[c] | - | 4.3[c] | - | 11.6[e] |
| ME | 0 | 3.7 | 0 | 2.5 | - | 9.4[d] | - | 5.5[c] |
| MI | 0 | 2.0 | 0 | 2.0 | • | •.• | - | 10.0[d] |
| IN | 0 | 0.7 | 0 | 2.5 | • | •.• | 0 | 2.5 |
| PR | • | •.• | • | •.• | 0 | 2.0 | 0 | 2.5 |

[a] See Appendix B for a description of behaviors

[b] + Initial observations overestimated subsequent observations
- Initial observations underestimated subsequent observations
0 Initial observations accurately represented subsequent observations

[c] $P < 0.05$

[d] $P < 0.01$

[e] $P < 0.001$

• No observations recorded

than 1/3 of their time in flapping flight low to the ground and often perched (Fig. 17a). Short-eared owls and burrowing owls rarely did anything except perch and fly low to the ground (Fig. 17b). Buteos soared more than any other group and often perched and flew low across the ranges (Fig. 17c). Falcons commonly used low flapping flight to traverse the area, but also often glided, soared, and perched (Fig. 17d).

Our analyses of behavior are based on the variety of behavior observed during an entire 1-min scan. Each unique behavior exhibited during the scan is recorded only once. It was necessary to analyze the entire scan sample rather than just the initial observation because initial observations tended to misrepresent behavioral repertoires of groups of species (Table 5). Initial observations underrepresented the occurrence of most

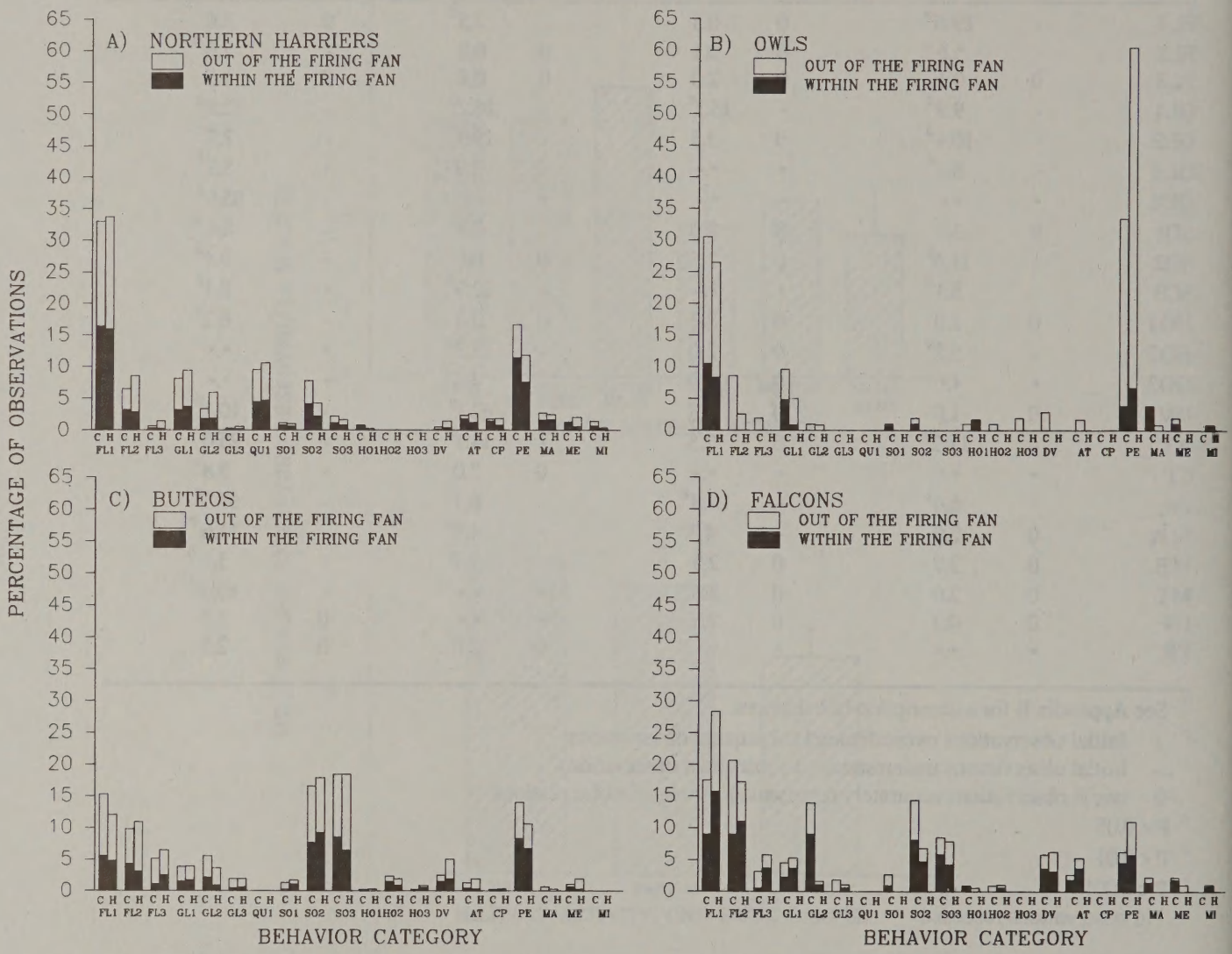

A) NORTHERN HARRIERS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
B) OWLS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
C) BUTEOS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
D) FALCONS
OUT OF THE FIRING FAN
WITHIN THE FIRING FAN
PERCENTAGE OF OBSERVATIONS
BEHAVIOR CATEGORY
BEHAVIOR CATEGORY
C H FL1 FL2 FL3 GL1 GL2 GL3 QU1 SO1 SO2 SO3 HO1 HO2 HO3 DV AT CP PE MA ME MI

Fig. 17. Full repertoire of behaviors recorded for 4 groups of raptors utilizing the military firing ranges. Percentage use of each behavior is compared on days without firing (C) and days with firing (H). Within each bar we show the percentage of each behavior recorded inside the firing fan relative to outside of the firing fan. Behavior codes are identified in Appendix 2.

behaviors, especially behaviors such as attacks (note that attacks were significantly under-represented in each species group except the owls; Table 5).

Visual inspection of Fig. 17 reveals that most species behaved similarly whether firing occurred or did not occur on the training ranges (compare C and H bars). Moreover, the distribution of behaviors inside the firing fan relative to outside the firing fan rarely was different on days that firing occurred compared to days without firing (compare shading in H versus C bars).

The most stringent test of the hypothesis that behavior was not influenced by military training is to compare behavior in versus out of the firing fan on firing (hot) versus non-firing (cold) days. If firing causes immediate behavioral shifts we would expect to see differences in the behavioral repertoires of birds in the fan on hot versus cold days. In particular, we expected birds to reduce their perching, low flights, and attacks while increasing their high altitude flights in the fan when firing occurred relative to when firing did not occur. This is tested by the 3-way interaction between behavior, location in or out of the fan, and activity on the range in our log-linear models of 9 behavioral categories (see METHODS for description of categories).

The null hypothesis that the activity on the range did not influence the repertoire of behavior in the firing fan could not be rejected (tests of the 3-way interaction for northern harriers: $G^2_{(8)} = 4.94$, $\underline{P} = 0.76$; owls: $G^2_{(8)} = 2.43$, $\underline{P} = 0.97$; buteos: $G^2_{(8)} = 12.6$, $\underline{P} = 0.13$; falcons: $G^2_{(8)} = 11.6$, $\underline{P} = 0.17$).

A less precise test of the influence of military training on raptor behavior can be made by comparing behavioral repertoires on firing versus non-firing days, regardless of whether the bird was inside or outside of the firing fan. Northern harriers and buteos behaved similarly regardless of the activity on the firing range (Fig. 18a,c; testing for 2-way interaction between behavior and range activity; northern harriers $G^2_{(16)} = 16.4$, $\underline{P} = 0.42$; buteos: $G^2_{(16)} = 19.0$, $\underline{P} = 0.27$). Owls tended to shift their behavioral repertoire depending on the activity of the range. They tended to perch more, fly less, and maneuver less on days with firing (Fig. 18b; $G^2_{(16)} = 23.7$, $\underline{P} = 0.10$). Falcons exhibited significantly different behavioral repertoires on days when firing occurred relative to days without firing (Fig. 18d; $G^2_{(16)} = 31.8$, $\underline{P} = 0.01$). Falcons perched more, flew low to the ground and attacked more, and flew at intermediate heights less on days when ranges were firing.

The occurrence and fate of prey capture attempts was not dependent upon military training activities. We observed 112 attempts to capture prey by raptors on training ranges; 28 (25%) were successful, 69 (61.6%) were unsuccessful, and the fates of 15 (13.4%) were not determined. Attempts occurred on hot versus cold training days and in versus out of the firing fan with similar frequency (25% were in the fan on hot days, 25.9% were in the fan on cold days, 30.4% were outside of the fan on hot days, and 18.8% were outside of the fan on cold days; $X^2 = 1.8$, 1 df, $\underline{P} = 0.18$). Furthermore, success rate did not differ with respect to military training or location of the attempt relative to the firing fan (3-way contingency table comparing success versus failure, in relative to out of the fan, on hot versus cold days: $X^2 = 0.23$, $\underline{P} = 0.63$).

Most species exhibited strong, fixed differences in their behavior in the firing fan relative to outside of the fan (testing for 2-way interactions between location with respect to fan and behavior: northern harrier: $G^2_{(16)} = 32.9$, $\underline{P} < 0.01$; buteos $G^2_{(16)} = 33.6$, $\underline{P} < 0.01$; owls $G^2_{(16)} = 29.5$, $\underline{P} = 0.02$; falcons $G^2_{(16)} = 12.9$, $\underline{P} = 0.68$). Northern harriers typically perched, conducted low stationary flights, and attacked within the

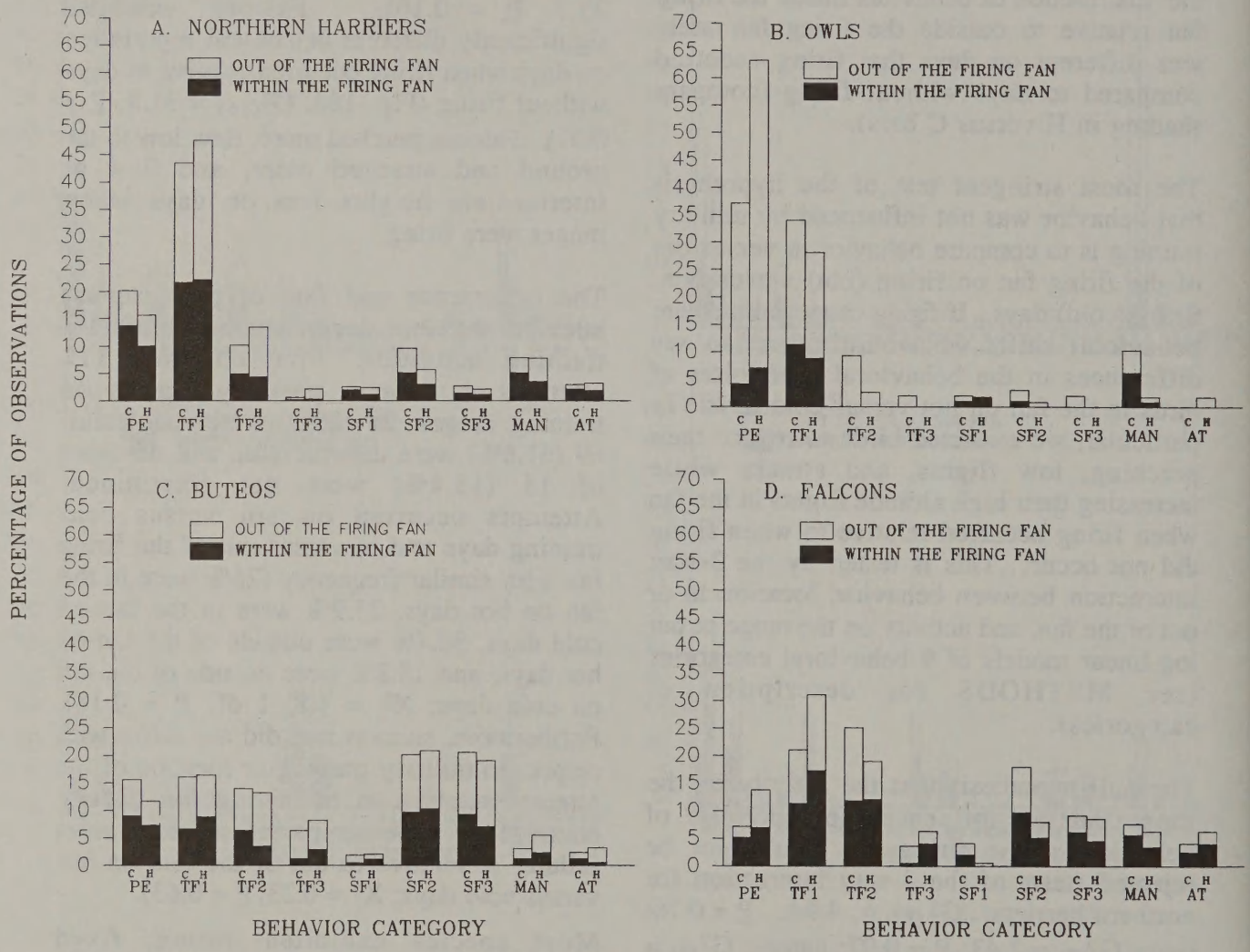



Fig. 18. Condensed repertoire of behaviors recorded for 4 groups of raptors utilizing the military firing ranges. See legend in Fig. 17 for detail.

firing fan, but traveled at low levels in and out of the fan with equal frequency (Fig. 18a). Owls rarely used the area within the firing fan, but most of the few observed maneuvers and low stationary flights were within the fan (Fig. 18b). Buteos used the areas in and outside of the fan with relatively equal frequency, but concentrated their perching inside the fan and rarely flew high over the fan (Fig. 18c). Falcons utilized the firing fans to a greater degree than the other species and did not show marked changes in their behavior inside relative to outside of the fan (Fig. 18d).

**Eagle Trapping and Initial Observations**

We captured 3 eagles (1 adult, 1 subadult, and 1 fledgling). The subadult (apparently a male based on size) was captured opportunistically on 11 February and radio-tagged even though its status as a local or wintering bird was unknown. One contact was made during March; we did not contact it again until systematic radio-tracking of prairie falcons began in April. Tracking teams occasionally received the eagle's signal, but the location was never inside the study area; therefore, only a general direction was recorded and specific locations were not determined. We also contacted the eagle's signal during aerial surveys in July. He was tracked to the mountains north of Emmett, Idaho. A tracking team localized the signal from the ground, but could not make visual contact.

The adult (apparently a male based on size) was captured on 19 February near the PP&L 119 nest site. We radio-tagged the eagle using the bow net method described (see METHODS), and monitored the bird after release for 1 hr 10 min and again on 22 February for 2 hr, at which time the backpack still appeared to be attached. Behavior monitoring began on 26 February and continued until 28 March, when we recovered the shed transmitter from below the nest. Review of observation notes indicated that the transmitter was probably removed between 22 February and 26 February, as observations after 26 February indicated that the male was consistently at the nest site. We believe the transmitter was probably in the nest until the week just prior to its recovery.

The fledgling (apparently a female based on size) was captured on 31 July in her natal territory (PP&L 119). She remained in her natal territory with her parents until 5 November.

DISCUSSION

**Influence of Telemetry Packages**

There was no significant effect of the 13-g backpack transmitter packages on the behavior or productivity of prairie falcons. Instrumented individuals resumed their courtship and nesting behavior within hours of being fitted with radios and exhibited levels of productivity that were statistically indistinguishable from control individuals. McCrary (1981) found backpack transmitters to have a similar lack of influence on red-shouldered hawks (*Buteo lineatus*). The only conspicuous behavioral change we noted was a short-term increase in preening behavior by newly instrumented birds, a common observation (Gilmer et al. 1974, McCrary 1981).

Control pairs showed slightly higher nesting success than pairs containing a radio-tagged falcon. This was especially true with females trapped and radio-tagged prior to incubation. However, the nesting failure of 2 of these females are suspect (Tick III failed before the radio was attached and Balls Basin Powerline nested just below an overlook frequently disturbed by tourists). Lack of an effect of radio-tagging on females is further suggested by the fact that radio-tagged females delivered prey to their

nestlings at rates similar to the 4-year average reported by Holthuijzen (1990) for falcons without transmitters.

Any difference in the productivity of radio-marked and control falcons is likely a reflection of our improved ability to monitor the fates of sites tended by instrumented falcons. Most nesting failures by prairie falcons in the SRBOPA from 1973-90 occurred during incubation (65.3% of 124 nesting attempts confirmed during incubation; BLM unpubl. data; see also Ogden and Hornocker [1977]). Individuals captured and radio-tagged prior to incubation were monitored throughout the risky incubation period, and their failures were detected. However, individuals captured later in incubation should be less prone to failure because the nesting attempt had already survived some of the failure-prone incubation period. We only were unable to determine the fate of 1 instrumented pair (Priest Rapids II was not monitored), but fates at 8 of 50 control pairs were undetermined; many of these could have failed early in incubation and gone unnoticed. Telemetry enabled us to detect at what rate nests typically failed; it was unlikely to be the reason that nests failed.

Why did instrumentation have no significant effects on falcons this year? We implemented several suggestions from Clugston (1990) that were likely responsible for lessening the effects of instrumentation. The most important adjustment made in 1991 was to trap away from the nest. We also redesigned the harness so that it included a leather breast patch to distribute the weight of the transmitter evenly across the falcon's sternum, and we streamlined the transmitter profile. We also were especially sensitive to our disturbance of a nesting pair; we did not trap during inclement weather, and generally spent less than 2 hr at each site prior to setting a trap.

**General Activity Patterns**

Raptors are strongly influenced by extrinsic factors, most notably patterns of prey abundance (Phipps 1979, Steenhof and Kochert 1988) and vagaries of the harsh desert climates (Harmata et al. 1978). Our results also indicate the importance of such factors. Prairie falcons reduced their activity (or at least they were less detectable) when wind speeds exceeded 40 km/h or temperatures fell below 18 C (Fig. 4). The seasonal pattern of falcon activity is a complex mix of an individual's reaction to these weather factors, seasonal differences in ground squirrel abundance, and the changing needs of its nestlings. Activity peaked in mid-May (Fig. 5 season 2, Fig. 15 early season), just when cold and windy conditions began to subside, juvenile ground squirrels were generally abundant (Smith and Johnson 1985), and nestlings were growing rapidly. As temperatures continued to increase and ground squirrels began to estivate (Van Horne et al. this volume), the numbers of falcons, and raptors in general (Fig. 15), declined until few birds remained by late August. Dispersal out of the study area is extremely variable, with some individuals remaining a month or more longer than others (Fig. 11), as previously noted by Dunstan et al. (1978).

Weather, prey availability, and the needs of nestlings also play a role in determining the strong daily activity cycles that we documented. Falcons remain near their aeries early in the morning and late in the evening but take repeated trips from the aerie to forage in mid-morning as well as in mid-to-late afternoon (Fig. 6, Fig. 14), as also noted by Dunstan et al. (1978), Harmata et al. (1978), and Sitter (1983). Our observations on military firing ranges suggest that a mid-morning peak in activity occurs for the entire raptor community, however these observations did not extend

long enough to evaluate the presence of a second, mid-afternoon peak (Fig. 15). Cold temperatures early in the morning and late in the evening and extremely warm temperatures around midday might reduce ground squirrel activity, making foraging at those times unprofitable. The energetic demands of the brood also may reduce the need for prey deliveries at midday and in the evening because nestlings get satiated from mid-morning and mid-afternoon feedings. The generally higher activity levels in late afternoon support Sitter's (1983) contention that adults overfeed nestlings to sustain them through the night. Changing energetic demands of nestlings might reduce the bimodal nature of adult activity after the middle of May when nestlings are rapidly growing and adult activity is high and relatively constant throughout the day (Fig. 6).

Prairie falcons roamed widely over our entire study area. We sampled all telemetry zones with equal intensity from mid-April to mid-July to describe accurately the relative use of the OTA. Use of the OTA was substantial; only 3 birds were never located inside the OTA boundaries, and many birds nesting beyond the OTA shadow made extensive use of the area (Table 1). Most falcons using the OTA concentrated their activity along its western edge where annual grasses and sagebrush appear to be most abundant; falcon use of the area of most human activity (inside the Range Road) was minimal. Eleven of 25 falcons never ventured inside the Range Road. Use of the OTA was conditional upon the level of activity on the firing ranges; when firing began the numbers of birds using the ranges declined (Fig. 15), and the number of telemetry fixes inside the OTA tended to be higher when the ranges were not firing relative to when they were firing.

Although the OTA was extensively used by many birds, the majority of falcons concentrated their activity in the extensive mosaic of big sage (*Artemisia tridentata*), winterfat (*Ceratoides lanata*) and annual grass west of the OTA and east of the Snake River Canyon (Fig. 8). Receiver sites located in these areas (Initial Point, Tombstone Butte, west side of Bigfoot Butte) picked up consistently more activity than those located within or adjacent to the OTA (Dorsey Butte, East side of Bigfoot Butte, Observation Point [OP] 8). This concentration of activity close to the nesting cliffs of the Snake River Canyon waned after mid-June, possibly because declining ground squirrel abundance and increasing nestling food requirements forced parents to range farther in search of prey.

**Footpad Length as an Indicator of Sex**

We found a highly bimodal distribution of footpad size when we measured 29-31 day old prairie falcons (Fig. 3); 2 distinct distributions were evident because no footpads of 86 mm were measured. It is likely that nestlings with footpads < 86 mm are males and those with larger footpads are females. Footpad length is correlated with sex in adult Golden Eagles (Edwards and Kochert 1986), but we need footpads on birds of known sex to confirm such a correlation in prairie falcons.

**Home Range Characteristics of Prairie Falcons**

It has been known for over a decade that prairie falcons nesting in the Snake River Canyon range extensively across the sage shrublands surrounding the canyon (Dunstan et al. 1978). However, our results indicate that falcon home ranges are much larger than previous work suggested. The average falcon we studied incorporated 21,388 ha (213.9 $km^2$) in its 95% core use area and regularly traveled 20 km from its nest. This home range estimate is 3 times as large as Dunstan et al.'s (1978) estimate of "mean size of maximum breeding range" (mean = 71.2 $km^2$, $\underline{n}$ = 18) and much larger than

Harmata et al.'s (1978) estimate for prairie falcons living in the Mojave Desert (mean = 59.3 $km^2$, $\underline{n}$ = 8). Haak (1982) determined relatively large male prairie falcon home ranges during incubation and brood-rearing in California (mean = 228 $km^2$, $\underline{n}$ = 9 birds with 7-98 locations per bird), but these appear to be minimum perimeter areas.

It is unlikely that our analysis procedure accounts for the large home ranges we discovered. Anderson (1984) also used harmonic mean methods to estimate prairie falcon home ranges in Colorado. He obtained enough data ($\underline{n}$ = 20 or more locations per bird) to estimate 1 male's home range; 90% core area = 2,658 ha. Only 1 of our adequately sampled males had a 90% core area smaller than Anderson's value (Table 1). The simplest explanation for our larger home range estimate lies in our tracking technique. The prior studies of falcon home ranges employed active pursuit of subjects, whereas we waited at established receiver sites and let the bird come to us. Contact with radio-tagged birds is often lost during active pursuit when birds range to the extremities of their home range. This can lead to underestimation of home range (Harmata et al. 1978). Our technique results in fewer fixes per unit time, but provides an unbiased, representative sample of spatial use throughout the study area.

Prairie falcons are not known to defend hunting territories (Dunstan et al. 1978), and our results on home range overlap support this notion. We documented considerable overlap in home range, especially among neighboring birds (Fig. 10). Extensive overlap suggests that prey is not economically worth defending because of either its distribution or abundance (Brown 1969). The latter is most likely in our study area because Townsend's ground squirrels are abundant in the sage/winterfat/annual grass habitat.

Our use of 3 or 4 trackers to triangulate on falcons enabled us to define precisely the error associated with each estimated location. Error ellipses associated with our best fixes are still large; we discarded thousands of fixes that did not meet our precision requirement of < 1000 ha. The distance between the bird and our receiver sites, signal bounce, movement of falcons, wide signal arc, and our conservative estimate of the variation in bearing error all could have contributed to our large error estimates (Springer 1979, Hupp and Ratti 1983). We are experimenting with analytical techniques that are more robust to signal bounce (the Andrews' estimator; Lenth [1981]) and evaluating alternative antenna designs to narrow the signal arc, but triangulation estimates of falcon locations will always have relatively large errors because these birds travel rapidly over vast distances. Our estimates of home range are the best possible, but as is true in all telemetry studies, they are <u>estimates</u> (Springer 1979).

**Influence of Military Training on Raptors**

There appears to be a cause and effect relationship between military training and raptor abundance on the training ranges. When firing of tanks, small arms, and mortars began, the number of raptors using the immediate area around the firing range declined (Figs. 15 and 16). This effect was most striking after mid-May (Fig. 15b, c) which was also the time when more falcons were located near receiver sites in the OTA (Fig. 5) and hence most vulnerable to training activities. The initial drop in abundance of raptors on firing ranges occurs between 0800 and 1000 hrs, exactly when firing typically commences.

Avoidance of firing might contribute to the strong effect that nesting inside the OTA shadow had on falcon ranging behavior and

attendance in the territory. Falcons nesting in the OTA shadow spent less time in their nesting territory and ranged farther from their aeries, especially as nestlings grew (Table 4), than falcons nesting west of the OTA. Thus, when the energetic demands of the nestlings were greatest, parents ranged more extensively from nests in the OTA shadow than from nests west of the OTA. Ranging farther from the nest seemingly compensated for the apparently poor foraging opportunities near the aerie because birds nesting in the OTA shadow provisioned their nestlings at rates equal to those attained by shorter ranging parents west of the OTA. However, ranging farther is a potentially dangerous tactic for at least 2 reasons: (1) Fledgling productivity tended (but not significantly) to increase with increased time spent by parents in the nesting territory. Perhaps the presence of parents in the territory helps thwart potential predators or reduce the chances of nestlings falling from their aeries. (2) Ground squirrels were abundant this year (Knick, this volume) so that extended hunting trips were often likely to end in success. In years of prey scarcity, falcons would be expected to range even farther (Harmata et al. 1978, Phipps 1979) which could cause a reduction in attendance and prey delivery rates and eventually lower fecundity.

Avoidance of firing is certainly not the only, or necessarily even the primary reason that birds nesting in the OTA shadow ranged farther than birds nesting west of the OTA. We speculate that sage shrublands and intervening grasslands holding vulnerable prey are less abundant due north of the OTA shadow, and we suspect that prey abundance is likewise greatly reduced due north of the OTA shadow relative to west of the shadow. These habitat and prey base differences would probably necessitate increased travel for breeding falcons to secure adequate prey. Results from studies 4 and 5 will allow us to test this speculation.

The importance of habitat differences west of the OTA relative to inside the OTA shadow is indicated by the relative distribution of prey types delivered to nestlings. Townsend's ground squirrels were important to falcons in both locations, but less so for birds nesting inside the shadow (Fig. 13).

These falcons tended to have less specialized diets, perhaps because of low ground squirrel abundance near the OTA or because they nested later in the season and had to feed their nestlings after many ground squirrels had already estivated. Their slightly lower reliance on Townsend's ground squirrels may be the reason that birds in the OTA shadow were able to remain in the study area longer than the more specialized birds west of the shadow.

All individuals are not adversely affected by military training. Many raptors utilized the firing ranges even when training was intense (Figs. 15 and 16). Moreover, the behavior of raptors that remained on the ranges during firing was similar to their behavior when firing did not occur (Figs. 17 and 18). This was especially true for the most common range resident, the northern harrier. These birds often used the firing range proper, and they appeared habituated to the intense disturbance. Harriers are reported to hunt areas recently disturbed by military activities (aerial bombing; Jackson et al. 1977). Owls, however, appeared less habituated to disturbance despite also inhabiting the ranges. They maneuvered and flew less, but perched more when firing occurred relative to when firing did not occur. Prairie falcons that remained on the ranges during firing might have opportunisitically foraged on dead or stunned prey. They exhibited more hunting behavior inside the firing fan when firing occurred than when firing did not occur. In fact, every species studied attacked more during days with firing than during days without firing. This could

indicate a short-term benefit of firing to raptors able to capitalize on disturbed, injured, or stunned prey.

It appears that all types of military training are not equally disruptive to raptors. Training that does not involve firing had negligible impacts on raptor abundance (Fig. 16a), and punctuating training with periods of inactivity could further reduce the impact of training (Fig. 16b). Experiments need to be conducted to determine if pauses in firing actually cause (rather than correlate with) raptors to reduce their avoidance of firing ranges.

**Post-fledging Mortality of Prairie Falcons**

The week prior to fledging and the 3-8 week period spent in the natal territory just after fledging represents a critical survival bottleneck to prairie falcons in the Snake River Canyon. Sitter (1983) reported that fledgling mortality can account for up to 56% of the total first year mortality and noted that 10 of 19 cases of nestling mortality occurred as young fell from nests while trying to fledge. Our pilot efforts to quantify post-fledging mortality support this view as we saw 1 nestling die after falling from the nest, and 1 of our radio-tagged fledglings died shortly after leaving the nest. The other radio-tagged fledgling successfully dispersed from the canyon, but its subsequent fate was unknown. The importance of mortality at this stage of the falcon's life history cannot be overstated. The magnitude of fledgling mortality is an important factor in assessing any effects on a population's dynamics that are ascribed to military activity.

## CONCLUSIONS

We have completed the first season of an ambitious attempt to study military training in relation to the behavior of raptors. We are pleased to report that our study methods have been benign and accurate. Radio-tagging had minor effects on prairie falcons and yielded new insights into their ranging behavior. We corroborated many previous findings on falcon nesting behavior such as the trend for prey delivery rates to increase with age of nestlings and size of the brood, but decrease with the timing of nesting (Holthuijzen 1990). Additionally, we found that activity patterns were bimodal and strongly influenced by wind and temperature as Harmata et al. (1978) also discovered. However, 1 major finding is at odds with all previously published work: our sample of prairie falcons ranged farther than previously determined. This reflects our extensive radio-tracking effort throughout the study area. This effort is justified because of the concern that military training in the OTA might influence raptors nesting along the Snake River Canyon; prairie falcons made extensive use of the OTA. Evidence from 1991 suggests that the effect of military training is minor. There is a short-term avoidance of firing ranges when firing occurs, which likely interacts with long-term habitat degradation to force falcons nesting in the OTA shadow to range farther than falcons nesting west of the shadow. This did not appear to affect the rate of food delivery to nestlings this year, but it could have serious effects in years when ground squirrels are scarce. It is critical to study this population of falcons under varying levels of prey abundance before drawing conclusions about the impact of military training.

## PLANS FOR NEXT YEAR

We will study the ranging habits of prairie falcons in 1992 with the same methods described for 1991. We plan on instrumenting 30 falcons in 1992 and will focus on obtaining more fixes per bird by increasing our tracking efforts slightly and implementing aerial tracking, if accuracy tests this winter suggest that aerial tracking is as precise as ground-based tracking. We will employ automated weather stations to sample wind speed and temperature while

we track falcons and observe their parental behavior. If funding is secured, we will expand our monitoring effort of post-fledging mortality.

Observations on military firing ranges will continue as in 1991. We will expand to survey raptor use of bivouac sites as well as firing ranges.

Research on golden eagles will be expanded. We will track 6 - 8 adults throughout the winter and breeding season to determine their ranging habits, hunting success, and habitat use. These behaviors will be compared between birds inhabiting primarily burned and primarily unburned habitat.

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Appendix A: Band combinations and physical characteristics of prairie falcons trapped in the SRBOPA, 1991.

| Date | Trap Site or Nesting Area | USFWS | Color Band | | | Time Held | Sex | Mass (g) | %Crop | Wing | | | Body | Treatment | | # Fledged |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | color | leg | code | (hr:min) | | | | span | width | chord | Circ. | N/B | Freq. | |
| 30 Jan | Swan Falls-W1 | 816-70179 | Blu | L | 4/C[d] | • | Male | • | • | • | • | • | • | N | | • |
| 08 Feb | Pleasant Valley H-pole | 1807-26015[a] | • | • | • | 1:48 | Female | 955 | 0-25 | 1060 | 175 | 335 | 293 | B | 4.578 | • |
| 14 Feb | Pleasant Valley H-pole | 1807-01214[a] | Blk | R | V/X | 0.52 | Female | 1140 | 0-25 | 1142 | 178 | 357 | 305 | B | 4.805 | • |
| 08 Mar | Priest Rapids I | 1807-01206 | Blk | R | V/M[d] | 1:30 | Female | 906 | 0-25 | 1096 | 180 | 360 | 295 | B | 4.160 | 0 |
| 08 Mar | Priest Rapids II | 816-70149 | Blu | L | 1/U | 1:26 | Male | 616 | 26-50 | 936 | 170 | 315 | 240 | B | 4.190 | • |
| 11 Mar | Mother Giant Upstream | 1807-01223 | Blk | R | V/H[d] | • | Female | 911 | 0-25 | 1034 | 199 | 335 | 255 | B | 4.090 | 1[e] |
| 12 Mar | Beercase Draw | 816-70255 | Blk | R | N/P | 1:21 | Male | 546 | 0-25 | 984 | 162 | 306 | 240 | B | 4.070 | 5 |
| 15 Mar | Balls Basin Powerline | 1807-01215 | Blk | R | V/U | 1:03 | Female | 896 | 0-25 | 1112 | 195 | 347 | 317 | B | 4.210 | • |
| 16 Mar | Cattleguard Gate | 816-70247 | Blk | R | N/A[d] | 1:29 | Male | 603 | 0-25 | 960 | 165 | 312 | 255 | B | 4.260 | 5 |
| 19 Mar | Wildhorse Face Fenceline | 1807-01227 | Blk | R | V/Z | 0:54 | Female | 996 | 0-25 | 1084 | 191 | 360 | 311 | B | 4.050 | 0 |
| 20 Mar | Ogden Rock Downstream | 1807-01221 | Blk | R | N/V | 1:05 | Female | 911 | 0-25 | 1070 | 197 | 347 | 300 | B | 4.100 | 0 |
| 21 Mar | Beecham | 816-70256 | Blk | R | N/N | 0:53 | Male | 503 | 0-25 | 940 | 164 | 309 | 250 | B | 4.020 | 3 |
| 28 Mar | Fawn Humpback | 816-70250 | Blk | R | V/Y | 1:07 | Male | 521 | 0-25 | 910 | 165 | 298 | • | B | 4.270 | 5 |
| 28 Mar | CSJ | 816-74715 | Blk | L | 0/E[d] | 1:01 | Male | 511 | 0-25 | 936 | 161 | 290 | 247 | B | 4.240 | 3 |
| 30 Mar | Powerline Mirror | 816-70251 | Blk | R | V/E | 1:26 | Male | 560 | 0-25 | 954 | 163 | 308 | 237 | B | 4.250 | 0 |
| 03 Apr | Priest Rapids/Wolf Draw | 816-70252 | Blk | R | 4/A | 2:45 | Male | 586 | 0-25 | 940 | 168 | 311 | 250 | N | | • |
| 05 Apr | Wildhorse SW | 816-70257 | Blk | R | N/D | 1:01 | Male | 595 | 0-25 | 980 | 164 | 306 | 240 | B | 4.480 | 1[e] |
| 10 Apr | Balls Basin Hamer | 1807-01220 | • | • | • | 1:33 | Female | 1095 | 26-50 | 1040 | 194 | 342 | 317 | B | 4.080 | 5 |
| 10 Apr | Henderson Draw | 1807-01230 | Blk | R | L/8 | 1:02 | Female | 856 | 0-25 | 1080 | 200 | 349 | 290 | B | 4.450 | 0 |
| 10 Apr | Bitch | 816-70262 | Blk | R | 4/B | 0:54 | Male | 581 | 0-25 | 958 | 154 | 340 | 264 | B | 4.180 | 4 |
| 12 Apr | Peregrine Chimney | 1807-01228 | Blk | R | G/8 | • | Female | 981 | 0-25 | 1022 | 189 | 364 | 313 | B | 4.420 | 5 |
| 13 Apr | Priest Upper | 816-70263 | Blk | R | 4/H | 1:12 | Male | 560 | 0-25 | 904 | 155 | 304 | 258 | B | 4.730 | 2 |
| 13 Apr | Hell Hole Gaging Station | 816-70179 | Blu | L | 4/C[d] | 0:49 | Male | 620 | 0-25 | 848 | 142 | 306 | 263 | B | 4.660 | 5 |
| 15 Apr | Cabin | 1807-01229 | Blk | R | K/8 | 1:15 | Female | 946 | 0-25 | 1092 | 191 | 344 | 313 | B | 4.990 | 4 |
| 17 Apr | Balls Pt Upstream | 987-53079 | Blu | L | 4/R[d] | 0:59 | Female | 876 | 0-25 | 1068 | 192 | 347 | 289 | B | 4.640 | 5 |
| 17 Apr | Powerline | 1807-01203 | Blk | R | V/S[d] | • | Female | 950 | 0-25 | • | • | • | • | N | | • |
| 18 Apr | Wildhorse Butte/Colt | 816-70258 | Blk | R | N/K | 0:49 | Male | 546 | 0-25 | 952 | 158 | 300 | 258 | N | | • |

Appendix A. Continued

| Date | Trap Site or Nesting Area | USFWS | Color Band | | | Time Held | Sex | Mass (g) | % Crop | Wing | | | Body | Treatment | | # Fledged |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | color | leg | code | (hr:min) | | | | span | width | chord | Circ. | N/B | Freq. | |
| 19 Apr | Wildhorse/Face Fenceline | 816-70264 | Blk | R | 4/K | 1:0 | Male | 556 | 0-25 | 986 | 159 | 308 | 232 | N | | • |
| 19 Apr | Wildhorse Butte NE | 1807-01231 | Blk | R | R/8 | 1:03 | Female | 946 | 0-25 | 1110 | 188 | 345 | 302 | B | 4.780 | 4 |
| 22 Apr | Tom Butte West | 1807-01232 | Blk | R | A/9 | 0:45 | Female | 926 | 26-50 | 1130 | 184 | 342 | 300 | B | 4.750 | 3 |
| 30 Apr | Tick III | 1807-01233 | Blk | R | U/8 | 0:55 | Female | 875 | 0-25 | 1050 | 185 | 340 | 305 | B | 4.440 | 0 |
| 01 May | Fever Basin Upstream | 1807-01204 | Blk | R | V/T[d] | 0:24 | Female | 706 | 0-25 | 1114 | 186 | 347 | 280 | N | | • |
| 03 May | Swan I Draw | 1807-01225 | Blk | R | B/8 | • | Female | 931 | 26-50 | 1070 | 184 | 346 | 283 | B | 4.320 | 2 |
| 03 May | Fever Basin | 1807-01226 | Blk | R | A/8 | 0:51 | Female | 856 | 0-25 | 1130 | 175 | 342 | 273 | B | 4.380 | 5 |
| 06 May | Fang | 1807-01234 | Blk | R | L/9 | 1:00 | Female | 951 | 26-50 | 1110 | 175 | 355 | 280 | B | 4.820 | 0 |
| 06 May | Balls Basin GE | 1807-10235 | Blk | R | C/8 | 0:57 | Female | 981 | 0-25 | 1120 | 175 | 348 | 305 | B | 4.950 | 4 |
| 06 May | Balls Basin GE | 816-70259 | Blk | R | 4/Y | 0:25 | Male | 591 | 0-25 | 980 | 170 | 304 | 245 | N | | • |
| 29 May | Balls Basin Hamer | 816-70260[b] | Blk | R | 4/G | • | Male | • | 0-25 | 964 | 158 | 305 | 270 | N | | • |
| 02 Jun | Fawn Draw | 1807-01202[c] | Blk | R | V/R | 0:34 | Female | 856 | 0-25 | 1106 | 192 | 340 | 276 | N | radio removed | • |
| 03 Jun | Spoon Upstream | 1807-01236[c] | Blk | R | D/8 | 0:25 | Female | 870 | 0-25 | 1084 | 186 | 341 | • | N | | • |

[a] Falcons trapped outside the SRBOPA for evaluation of 1991 radio-backpack attachment methods
[b] Falcon trapped during attempt to recapture female that recently had shed radio-backpack
[c] Falcons caught during efforts to trap birds with 1990 radio-transmitters still attached
[d] Falcons banded prior to 1991 field season
[e] Incomplete fledge counts
Color: Blu=Blue, Blk=Black
Treatment: N=None, B=Backpack radio-transmitter

APPENDIX B: Codes used during observations of raptor and military activity on firing ranges.

BEHAVIOR CATALOGUE

LEVEL 1: SIMPLE ACTIONS

FL - FLAPPING FLIGHT
GL - GLIDING FLIGHT - gliding flight, with loss of altitude
SO - SOAR - gliding in circles or a similar pattern with a gain in altitude
DV - DIVE - rapid loss of altitude (more rapid than a normal glide for the species)
HO - HOVER - flight with basically no ground speed
PE - PERCH - inactive or active, on the ground or an elevated position
AT - ATTACK - an attack on prey
PR - PREEN

LEVEL 2: COMPLEX ACTIONS

MA - MANEUVERS, INTRASPECIFIC - multiple, rapid changes of position and flying while interacting with the same species
ME - MANEUVERS, INTERSPECIFIC - multiple, rapid changes of position and flying while interacting with a different species
MI - MANEUVERS, INDIVIDUAL - multiple, rapid changes of position and flying while alone
FE - FEEDING - eating prey
CP - CARRYING PREY - flight with prey in talons
QU - QUARTERING - specific to harriers: hunting pattern consisting of a series of right angle turns
IN - INTERACTION with animal other than bird or prey

ALTITUDE above ground during the observed behavior is recorded as: 1 (0 to 10 meters), 2 (10 to 30 meters or 3 (over 30 meters)

MILITARY ACTIVITY CATALOGUE

0. CONTROL: NO ACTIVITY

1. TANKS
   A) Preparation: Equipment or weapons on range setting up before activities begin
   B) Moving
   C) Moving and firing main turret gun (105 mm) or machine guns
   D) Stationary and firing main turret gun (105 mm)
   E) Stationary and firing machine guns
   F) Stationary and firing machine guns and main turret gun
   G) Idle: between different activities, or a pause in activity

2. MACHINE GUNNERY
   A) Preparation
   B) Firing
   C) Idle

3. HELICOPTERS
   A) Preparation
   B) Flying
   C) Flying and firing
   D) Idle

4. MORTAR FIRE
   A) Preparation
   B) Firing
   C) Idle

5. TRAFFIC on RANGE ROAD
   A) Convoys of wheeled vehicles (generally faster)
   B) Convoys of track vehicles (slower)

6. SMALL ARMS FIRE
   A) Preparation
   B) Firing
   C) Idle

7. LASER FIRE
   A) Preparation
   B) Firing
   C) Idle

8. MISSILE FIRE
   A) Preparation
   B) Firing
   C) Idle

# Raptor Distribution and Use of the Orchard Training Area (OTA) and Adjacent Areas

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*Annual Summary*

*We sampled 190 point count sites throughout the Integrated Study Area (ISA), located within the Snake River Birds of Prey Area (SRBOPA). Seventy sites were located within the Orchard Training Area (OTA), with 120 sites in the non-OTA ISA. In 559 point counts conducted between 22 April and 15 July 1991, 2291 detections of raptors and ravens of 14 species were recorded. Of the sightings, 64% (1475) were of common ravens (Corvus corax), while northern harriers (Circus cyaneus), prairie falcons (Falco mexicanus), red-tailed hawks (Buteo jamaicensis), golden eagles (Aquila chrysaetos), Swainson's hawks (Buteo swainsoni), and ferruginous hawks (Buteo regalis) accounted for 30% of the detections. An average of 4.1 detections was recorded per 20-min census. There was no difference between total numbers of detections inside and outside the OTA. We counted more birds in the morning (4.4 detections/count) and evening (4.2 detections/count) than in the afternoon (3.7 detections/count), and more birds in the northwest half of the ISA (5.8 detections/count) than in the southeast portion (2.5 detections/count). Because an adequate statistical model is still being investigated, the results reported here are descriptive in nature; no inferences can be made.*

## OBJECTIVES

1. Complete mapping of all driveable roads in the expanded study area.
2. Select 200 random sites in the Integrated Study Area, 125 outside the OTA and 75 inside the OTA.
3. Locate and describe each site on the basis of habitat characteristics and unique attributes.
4. Determine acceptable non-OTA match points for as many OTA points as possible.
5. Conduct 20-min point counts at each site during each of the 3 diurnal periods.
6. Evaluate breeding season results for differences in raptor and raven detections inside and outside the OTA during different times of day, and during days of military training compared with days of no training.

## INTRODUCTION

Bureau of Land Management (BLM)/Idaho Army National Guard (IDARNG) Study 1 is

described in the "Research Plan to Assess the Impacts of Habitat Alteration in the Snake River Birds of Prey Area, 15 January 1991 Revision." The overall objective of Study 1 is to provide information about the probability that a given tract of land in the Snake River Birds of Prey Area (SRBOPA) will be used by a certain species of raptor under a given set of conditions (season, time of day, presence/absence of military activity). This information will allow managers to schedule military training for time periods and locations that will have minimal impacts on birds of prey and allow them to prioritize areas for habitat protection and/or restoration.

Study 1 is a year-round project with 3 field seasons a year: breeding (1 March - 15 July), dry (16 July - 31 October), and winter (1 November - 28/29 February). Although observations were conducted during all 3 seasons in 1991, this report includes preliminary results of only the breeding season.

## METHODS

### Road mapping

The Integrated Study Area (ISA) was expanded in late 1990, thus including several tracts of public and private land that had not been part of the pilot study. The new ISA (Fig. 1) is delineated on the west by the Ada/Canyon County line and on the east by the Range 5/6 township line; the northern boundary roughly follows the railroad right-of-way, and the southern boundary is the north rim of the Snake River Canyon. Because all Study 1 points must be located within 100 m of driveable roads, all roads not included in road surveys of the original ISA were ground-truthed, mapped, and added to the road database of the BLM's Geographic Information System (GIS).

### Site Selection

The entire study area was divided up into 3 north-south zones based upon distance from the canyon rim to allow proportionate sampling throughout the north-south precipitation gradient. Zone boundaries were assigned at 9 km, 17 km, and 25 km north of the rim. The area was further divided into approximately equal east and west units by an arbitrary boundary perpendicular to the canyon rim, thereby creating 6 zones, each with an OTA and off-OTA component (Fig. 2).

The area of each OTA and off-OTA component within each zone was calculated, and a proportionate number of sites was assigned to each component of each zone, for a total of 75 points for the OTA and 125 points for the off-OTA ISA (Table 1). The target number of sites, 200, represents the maximum number of non-overlapping sites that can be fitted into the study area given the requirements that each point be located within 100 m of a road and have visibility to 1000 m over at least 75% of its area.

The research plan (Watson and Strickler 1991) called for each OTA point to be paired with an off-OTA point in the same zone on the basis of the distribution of vegetation types, heterogeneity, and unique attributes. For each OTA point, a large number of "candidate" points (i.e., points in the same zone outside the OTA) were to be generated and described by the GIS, and the off-OTA point with the greatest degree of similarity was to be chosen to create a pair. In order to test this method of pairing, a similarity index (Pianka 1973) was applied to the spectral classes of the satellite images of the SRBOPA for 138 randomly-chosen sample points. However, field tests of 8 of the resultant pairs that were calculated to have high (> 0.80) similarity values showed little correlation between visual estimates of

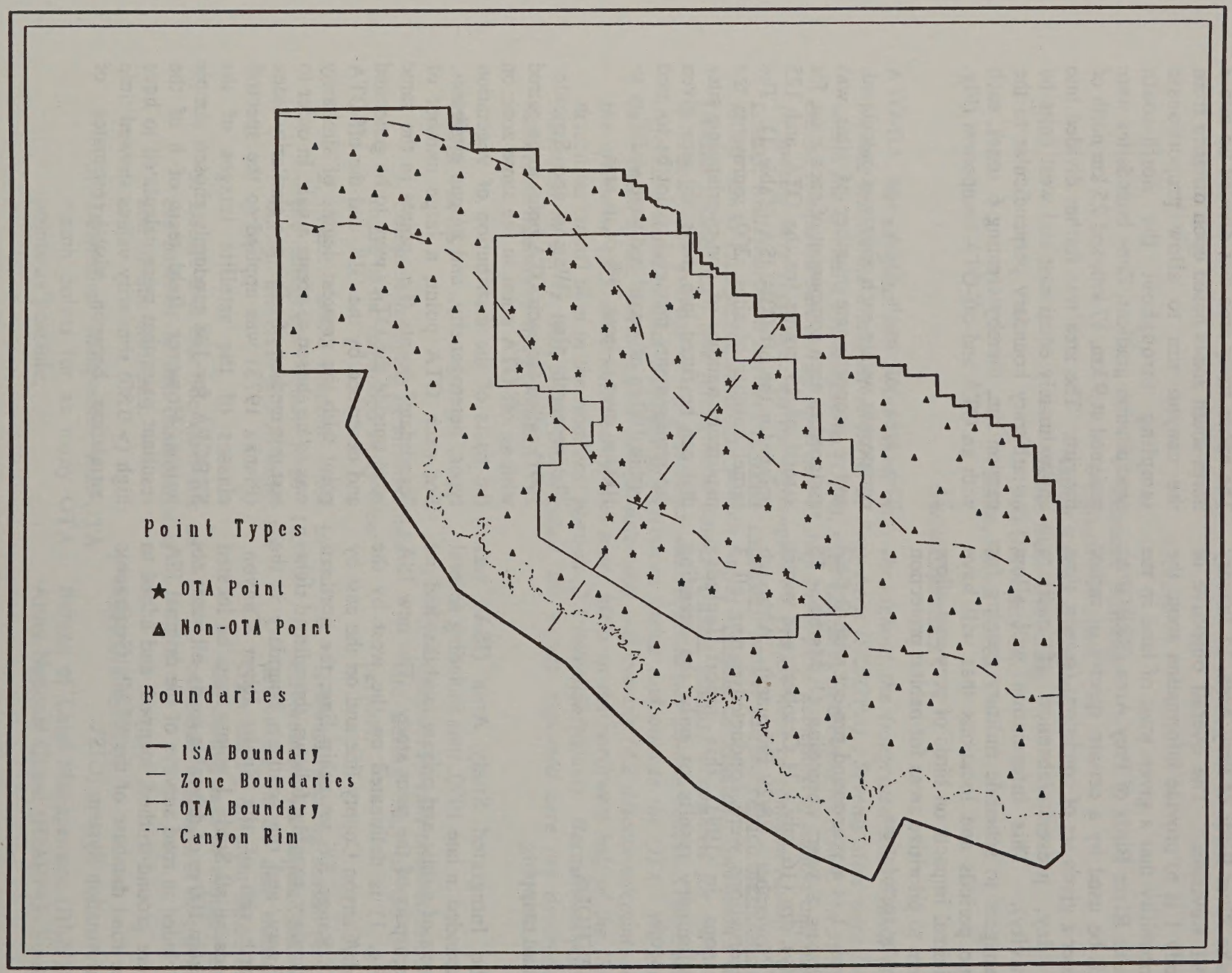


Fig. 1. Study 1 study area, zones, and sample site distribution.

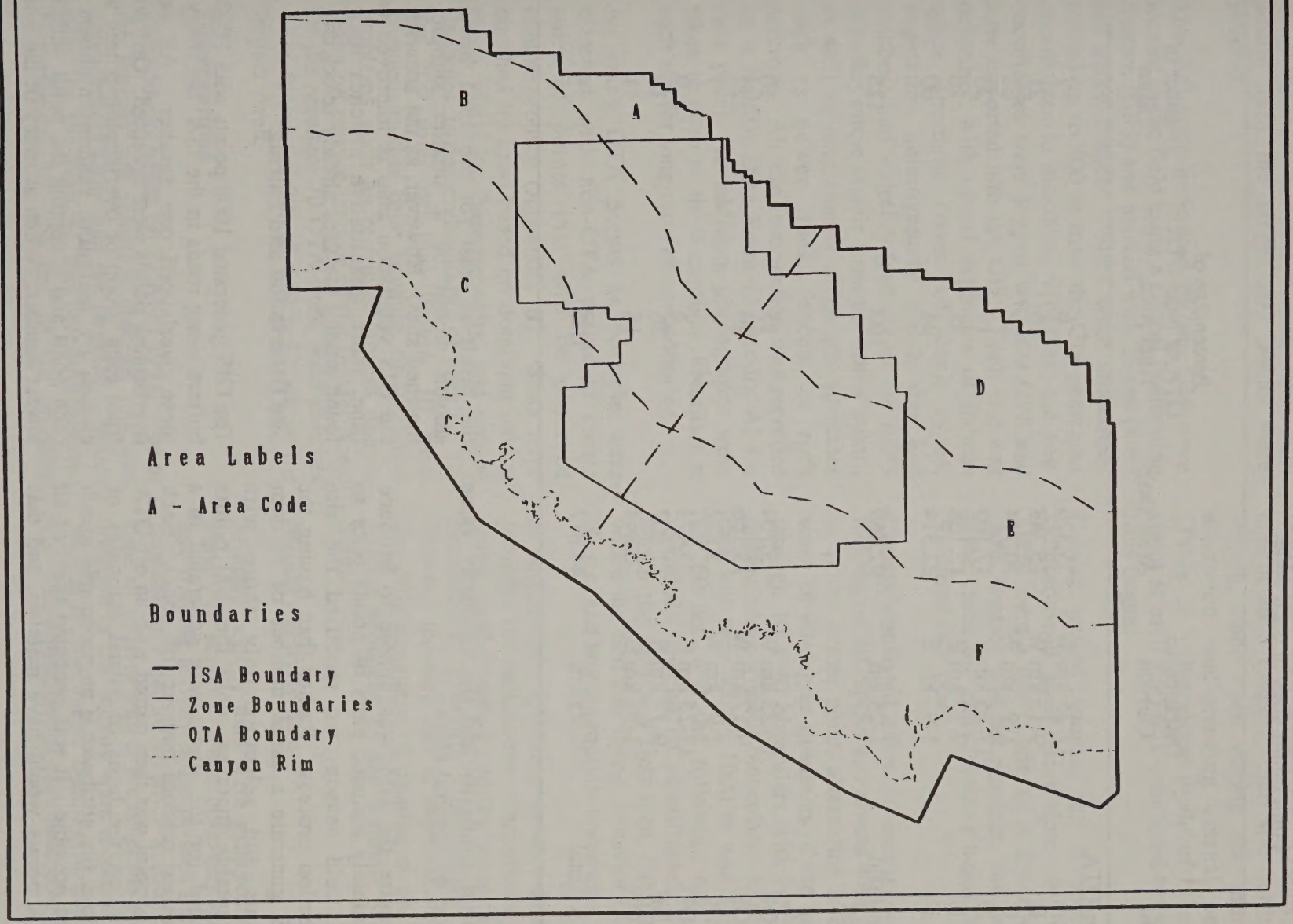


Fig. 2. Study 1 study area zones.

Table 1. Area of Study 1 zones inside and outside the OTA and the apportioned number of point count sites in each zone.

| Zone | Distance to Canyon | Area (ha) | Percentage of OTA or Non-OTA Total Area | Number of Sites |
|---|---|---|---|---|
| Non-OTA | | | | |
| A | 17-25 km W | 5,320 | 6 | 7 |
| B | 9-17 km W | 15,248 | 16 | 21 |
| C | 1-9 km W | 20,714 | 22 | 28 |
| D | 17-25 km E | 17,105 | 18 | 23 |
| E | 9-17 km E | 12,168 | 13 | 16 |
| F | 1-9 km E | 22,314 | 24 | 30 |
| Non-OTA Total | 1-25 km | 92,869 | 100 | 125 |
| OTA | | | | |
| OA | 17-25 km W | 5,704 | 13 | 10 |
| OB | 9-17 km W | 13,166 | 29 | 22 |
| OC | 1-9 km W | 3,822 | 9 | 7 |
| OD | 17-25 km E | 3,474 | 8 | 6 |
| OE | 9-17 km E | 11,807 | 26 | 19 |
| OF | 1-9 km E | 6,844 | 15 | 11 |
| OTA Total | 1-25 km | 44,817 | 100 | 75 |

habitat similarity and the similarity value based on spectral class.

Because the GIS was unable to produce accurately matched pairs of points prior to the field season, we modified the site selection process. Rather than having the GIS generate a large number of random points and selecting only those with acceptable matches, only the 200 points needed for the study were generated in a stratified random manner (by zone). Each OTA point was then paired with an off-OTA point on the basis of visual estimates of various site attributes if an acceptable match were possible. It was accepted that not all OTA points would have matches, and that the result at least for the 1991 breeding season would be a smaller sample of matched sites. However, as the accuracy of the GIS vegetation map is improved over time, more quantitative matches may be found among the sites already selected.

**Site Description and Pairing**

The GIS generated 1000 points with 1000-m buffers along roads in the ISA, but many of these overlapped one another. All non-overlapping points were accepted. One point from each group of overlapping points was chosen by assigning random numbers to each point and accepting the point with the lowest number. When as many of the initial

1000 points as possible had been accepted, the process was repeated with 1000 new points until the target 200 points were selected.

The 200 sites generated by the GIS were located in the field using a Global Positioning System (GPS) and marked with 15-cm (6-in) red stake chasers. Sites were sometimes moved up to 400 m from the GIS-generated coordinates to maximize visibility; the new coordinates were logged with the GPS and later imported into the GIS. Each site was described with visual estimates of habitat types (percent cover of each type), vegetation heterogeneity (patch size and number), and visibility (percent of the 1000-m radius circle visible from the center point), as well as assessments of unique attributes such as power lines, fences, or rock outcrops. All site information was recorded on a Habitat Data Form (Appendix A) for each point. In addition, photographs were taken in each of the 4 cardinal directions at each site for long-term photomonitoring.

As many OTA points as possible were matched with non-OTA points to create pairs of points that will be observed simultaneously (Appendix B). Sites were matched by hand based on dominant habitat types, visibility, heterogeneity, and unique attributes, in descending order of priority. Of the 200 total original points, 10 were rejected at this time because of logistical problems such as restricted access due to being on private land or in the Impact Area. Of the resultant 70 OTA sites, good matches were found for 32, of which 12 are in the Impact Area.

## Observations

Point counts began on 22 April 1991. Due to the lengthy site selection process, this was considerably later than the targeted 1 March date for the start of the breeding season. Nevertheless, by the end of the breeding season all but 11 of 570 counts for the season had been completed. Counts were conducted 3 times at each site during the season, once each during the morning, afternoon, and evening diurnal periods (Table 2). One entire cycle of counts (1 count at each site) was completed before the next began.

During paired counts, the 2 observers synchronized their start times by radio. There were a few counts ($\underline{n} < 25$) in which radio contact was not possible, but even in these cases the paired counts began within 30 min of each other.

Counts consisted of a 20-min period of looking for all raptors and ravens within 1000 m of the center point, alternating intensive scans of 90-degree quadrants of the horizon through 10 x 40 binoculars with brief 360-degree scans without binoculars. Every bird that was seen within 1000 m was observed for 60 sec, and the following data were recorded: species (if identifiable), time at which the bird was first seen, habitat over which the bird was flying, behavior over the 60 sec, and any appropriate comments.

In addition, the following weather data were recorded for each count: temperature, wind speed, wind direction, and sky cover. Hourly barometric pressure information was obtained for each day of observations from the daily summary of weather at the Boise Airport produced by the National Weather Service.

### Military activity data

Military activity data were gathered from a variety of sources. First, observers recorded any training activity heard or seen during or immediately before or after a count. The time of activity and, if possible, the type and location of the activity were recorded on the standard Observation Data Form (Appendix C). The limitations of such field observations

Table 2. Time of day for 3 diurnal time periods for each 2-week period of the year, based on sunrise and sunset at Boise, Idaho, mountain standard time, published by the U.S. Naval Observatory. Note: * indicates daylight savings time.

| Date | Morning | Afternoon | Evening |
|---|---|---|---|
| 1-15 Jan | 0818-1118 | 1119-1419 | 1420-1720 |
| 16-31 Jan | 0815-1121 | 1122-1428 | 1429-1735 |
| 1-15 Feb | 0802-1120 | 1121-1439 | 1440-1758 |
| 16-28 Feb | 0742-1113 | 1114-1445 | 1446-1817 |
| 1-15 Mar | 0722-1106 | 1107-1451 | 1452-1836 |
| 16-31 Mar | 0656-1055 | 1056-1455 | 1456-1855 |
| 1-4 Apr | 0627-1041 | 1042-1456 | 1457-1911 |
| 5-15 Apr* | 0727-1141 | 1142-1556 | 1557-2011 |
| 16-30 Apr* | 0701-1131 | 1132-1602 | 1603-2033 |
| 1-15 May* | 0638-1121 | 1122-1605 | 1606-2049 |
| 16-31 May* | 0619-1114 | 1115-1610 | 1611-2106 |
| 1-15 Jun* | 0607-1111 | 1112-1616 | 1617-2119 |
| 16-30 Jun* | 0603-1111 | 1112-1620 | 1621-2127 |
| 1-15 Jul* | 0607-1114 | 1115-1622 | 1623-2130 |
| 16-31 Jul* | 0617-1119 | 1120-1622 | 1623-2124 |
| 1-15 Aug* | 0634-1123 | 1124-1615 | 1616-2108 |
| 16-31 Aug* | 0649-1129 | 1130-1610 | 1611-2049 |
| 1-15 Sep* | 0708-1132 | 1133-1557 | 1558-2022 |
| 16-30 Sep* | 0725-1135 | 1136-1546 | 1547-1957 |
| 1-15 Oct* | 0742-1136 | 1137-1531 | 1532-1926 |
| 15-24 Oct* | 0800-1140 | 1141-1521 | 1522-1900 |
| 25-31 Oct | 0700-1040 | 1041-1421 | 1422-1800 |
| 1-15 Nov | 0720-1045 | 1046-1411 | 1412-1736 |
| 16-30 Nov | 0740-1052 | 1053-1405 | 1406-1411 |
| 1-15 Dec | 0758-1102 | 1103-1407 | 1408-1712 |
| 16-31 Dec | 0812-1111 | 1112-1411 | 1412-1711 |

are twofold: a) actual type and location of training are difficult to assess, especially for artillery, which may be heard but not seen; and b) some types of training, e.g., maneuvers and bivouacs, could take place close to the count site without the observer hearing or seeing the training if, for example, the activity were on the opposite side of a butte or hill from the count site.

Two additional sources of military activity data were provided by the IDARNG. The Range Management Input Worksheets provided general information of the daily activity of a particular military unit, including number of personnel, number and type of vehicles and aircraft, and amount and type of ammunition. These worksheets indicated that a certain number of people and equipment were present in a very general training area (usually 1 of 10 sectors into which the OTA is divided) during a 24-hr period, but gave no specific time, duration, or location of the activity. The other IDARNG document used was the Cinder Cone log book. A record of all communications with

the range control center, the Cinder Cone log was primarily useful for determining when a firing range went "hot" or "cold." A "hot" range is simply one on which firing has been approved; the designation does not indicate if or when firing actually occurred.

Because of the shortcomings of the available military activity data, it was not appropriate to assign rigorous designations of "military training" or "no military training" to each point count based on the site's proximity to a particular type of military activity during a specific time period. Instead, the "training" label was assigned to those OTA counts that took place on a day during which any military activity occurred at any time in the same sector as the count site, or in an adjacent sector; the "no training" label fell on those OTA counts that were made when no training activity took place in the same or an adjacent sector at any time during the same calendar day.

Comparisons of raptor activity during periods of military training and periods of no training were performed only on paired sites because of the impracticality of assigning "training" or "no training" labels to unpaired off-OTA points.

### Observer Comparison

Breeding season total counts for each observer were compared for raptors and ravens, raptors only, and individual species. We tried to have the 3 counts at each site conducted by each of the 3 observers so that no observer concentrated her counts in a particular area, time of day, or cycle. For the most part, this was possible; no site had counts conducted by fewer than 2 different observers.

### Analysis

Point count data gathered in this study have a non-normal distribution and, since more than 1 count is conducted at each site, require repeated-measures methods of statistical analyses. Therefore, traditional statistical tests are not appropriate for analysis of these data; the assumption of independence of most non-parametric tests is violated with our data, and using the repeated measures techniques of which we are aware, the assumption of normality is not met. We are currently investigating repeated-measures models for use with categorical data.

Because we have not yet found a valid method of statistical analysis, the results presented here can only be descriptive. No tests are given, and no inferences should be made regarding apparent trends or patterns. This report, therefore, is limited to presenting data from the 1991 breeding season; any discussion of those results would be premature at this time.

## RESULTS

### Raptor and Raven Detections -- Overall

In 559 point counts of 20 min each, sightings of 2291 raptors and ravens were made, for an average of 4.1 sightings per count (SD =4.6). Of the birds counted, 64% (1475) were common ravens 10% (226) were northern harriers, and 7% (163) were prairie falcons. No other single species accounted for > 4% of the total season count (Table 3).

More birds were seen during the morning (4.4 birds/count) and evening (4.2 birds/count) periods than in the afternoon (3.7 birds/count). Ravens tended to be seen more in the morning (3.1 birds/count) than in the afternoon (2.5 birds/count) or evening (2.4 birds/count), whereas raptors (excluding ravens) were observed more in the evening (1.8 birds/count) than in the morning (1.4 birds/count) or afternoon (1.2 birds/count; Table 4).

Table 3. Point count totals, means, and standard deviations (SD) for 1991 breeding season.

| | All ISA Sites | | | | OTA Sites | | | Non-OTA Sites | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Total | Mean | SD | Total | Mean | SD | Total | Mean | SD |
| # of Counts | 559 | -- | -- | -- | 204 | -- | -- | 355 | -- | -- |
| Total | 2291 | 100 | 4.10 | 4.6 | 838 | 4.11 | 4.9 | 1453 | 4.09 | 4.4 |
| Raptors | 816 | 36 | 1.46 | 1.7 | 285 | 1.40 | 1.8 | 531 | 1.50 | 1.6 |
| CORA | 1475 | 64 | 2.64 | 4.2 | 553 | 2.71 | 4.4 | 922 | 2.60 | 4.0 |
| NOHA | 226 | 10 | 0.40 | 0.8 | 77 | 0.38 | 0.9 | 149 | 0.42 | 0.7 |
| PRFA | 163 | 7 | 0.29 | 0.6 | 65 | 0.32 | 0.7 | 98 | 0.28 | 0.6 |
| RTHA | 92 | 4 | 0.16 | 0.4 | 19 | 0.09 | 0.3 | 73 | 0.21 | 0.5 |
| GOEA | 80 | 3 | 0.14 | 0.4 | 35 | 0.17 | 0.4 | 45 | 0.13 | 0.4 |
| SWHA | 77 | 3 | 0.14 | 0.6 | 21 | 0.10 | 0.4 | 56 | 0.16 | 0.6 |
| FEHA | 47 | 2 | 0.08 | 0.3 | 21 | 0.10 | 0.3 | 26 | 0.07 | 0.3 |
| SEOW | 21 | 1 | 0.04 | 0.2 | 6 | 0.03 | 0.2 | 15 | 0.04 | 0.3 |
| RLHA | 21 | 1 | 0.04 | 0.2 | 14 | 0.07 | 0.3 | 7 | 0.02 | 0.2 |
| AMKE | 12 | 0.5 | 0.02 | 0.2 | 3 | 0.01 | 0.1 | 9 | 0.03 | 0.2 |
| BUOW | 5 | 0.2 | 0.009 | 0.1 | 0 | -- | -- | 5 | 0.01 | 0.1 |
| TUVU | 5 | 0.2 | 0.009 | 0.1 | 0 | -- | -- | 5 | 0.01 | 0.2 |
| COHA | 2 | 0.09 | 0.003 | 0.1 | 1 | 0.005 | 0.1 | 1 | 0.003 | 0.1 |
| SSHA | 1 | 0.04 | 0.002 | -- | 0 | -- | -- | 1 | 0.003 | 0.1 |
| UNID | 62 | 3 | 0.11 | 0.4 | 21 | 0.10 | 0.4 | 41 | 0.12 | 0.4 |

All Birds = all raptor species and ravens; Raptors = all raptor species (excluding ravens); CORA = common raven (*Corvus corax);* NOHA northern harrier (*Circus cyaneus);* PRFA = prairie falcon *(Falco mexicanus*); RTHA = red-tailed hawk (*Buteo jamaicensis);* GOEA = golden eagle (*Aquila chrysaetos);* SWHA = Swainson's hawk *(Buteo swainsoni*); FEHA = ferruginous hawk *(Buteo regalis*); SEOW = short-eared owl *(Asio flammeus);* RLHA = rough-legged hawk (*Buteo lagopus);* AMKE = American kestrel (*Falco sparverius);* BUOW = burrowing owl (*Athene cunicularia*); TUVU = turkey vulture *(Cathartes aura*); COHA = Cooper's hawk (*Accipiter cooperii*); SSHA = sharp-shinned hawk (*Accipiter striatus*); UNID = unidentified raptor.

Table 4. Point count totals, means, and standard deviations (SD) for all ISA sites by diurnal period, for major groups of birds only. All means are detections per count.

| | Morning | | Afternoon | | Evening | |
|---|---|---|---|---|---|---|
| | Total | Mean (SD) | Total | Mean (SD) | Total | Mean(SD) |
| n | 192 | -- | 187 | -- | 180 | -- |
| All Birds | 849 | 4.42 (4.7) | 689 | 3.68 (4.3) | 753 | 4.18 (4.8) |
| Raptors | 260 | 1.35 (1.5) | 231 | 1.24 (1.3) | 325 | 1.81 (2.0) |
| Ravens | 589 | 3.07 (4.4) | 458 | 2.45 (3.9) | 428 | 2.38 (4.1) |

There has been some debate regarding the possible existence of a northwest-southeast vegetation gradient in the SRBOPA.The vegetation on the northwest side of the study area appears to support more shrubs, while the vegetation on the south-east side consists to a greater extent of grasses and exotic annuals. Results of the season's counts were examined for corresponding differences in raptor numbers between the relatively equal northwest and southeast units. Differences in numbers of raptors and ravens counted on the northwest and southeast sides of the ISA were substantial (Table 5): 5.8 birds/count on the northwest side and 2.5 birds/count on the southeast. More birds were seen in the northwest for ravens (3.8 vs. 1.6 birds/count) and for raptors (2.0 vs. 0.9 birds/count), as well as for most individual species.

Table 5. Point count totals, means, and standard deviations (SD) for all ISA sites by southeast and northwest unit of the Integrated Study Area. All means are detections per count. See Table 3 for species codes.

| | Southeast ISA | | Northwest ISA | |
|---|---|---|---|---|
| | Total | Mean (SD) | Total | Mean (SD) |
| n | 286 | -- | 273 | -- |
| All Birds | 715 | 2.50 (3.2) | 1576 | 5.77 (5.2) |
| Raptors | 266 | 0.93 (1.7) | 550 | 2.01 (1.9) |
| CORA | 449 | 1.57 (3.0) | 1026 | 3.76 (4.9) |
| NOHA | 73 | 0.26 (0.6) | 153 | 0.56 (0.9) |
| PRFA | 48 | 0.17 (0.5) | 115 | 0.42 (0.7) |
| RTHA | 33 | 0.12 (0.4) | 59 | 0.22 (0.5) |
| GOEA | 18 | 0.06 (0.2) | 62 | 0.23 (0.5) |
| SWHA | 26 | 0.09 (0.4) | 51 | 0.19 (0.7) |
| FEHA | 20 | 0.07 (0.3) | 27 | 0.10 (0.4) |
| SEOW | 8 | 0.03 (0.2) | 13 | 0.05 (0.3) |
| RLHA | 11 | 0.04 (0.2) | 10 | 0.04 (0.2) |
| AMKE | 4 | 0.01 (0.1) | 8 | 0.03 (0.2) |
| BUOW | 3 | 0.01 (0.1) | 2 | 0.01 (0.1) |
| TUVU | 1 | 0.003 (0.06) | 4 | 0.01 (0.2) |
| COHA | 1 | 0.003 (0.06) | 1 | 0.003 (0.06) |
| SSHA | 0 | -- | 1 | 0.003 (0.06) |
| UNID | 20 | 0.07 (0.3) | 42 | 0.15 (0.5) |

Table 6. Point count means and standard deviations (SD) for all ISA sites inside and outside the OTA by diurnal period. All means are detections per count. See Table 3 for species codes.

| | Morning | | Afternoon | | Evening | |
|---|---|---|---|---|---|---|
| | OTA Mean(SD) N = 70 | Non-OTA Mean(SD) N = 121 | OTA Mean(SD) N = 69 | Non-OTA Mean(SD) N = 119 | OTA Mean(SD) N = 65 | Non-OTA Mean( SD) N = 115 |
| All Birds | 4.53 (4.8) | 4.32 (4.6) | 3.06 (3.4) | 4.09 (4.7) | 4.77 (6.2) | 3.85 (3.8) |
| Raptors | 1.20 (1.7) | 1.41 (1.3) | 1.14 (1.1) | 1.32 (1.5) | 1.88 (2.4) | 1.77 (1.8) |
| CORA | 3.33 (4.5) | 2.91 (4.4) | 1.91 (2.9) | 2.77 (4.4) | 2.89 (5.4) | 2.09 (3.1) |
| NOHA | 0.57 (1.2) | 0.45 (0.7) | 0.14 (0.4) | 0.31 (0.6) | 0.42 (0.9) | 0.50 (0.8) |
| PRFA | 0.26 (0.7) | 0.24 (0.5) | 0.30 (0.7) | 0.22 (0.6) | 0.40 (0.7) | 0.37 (0.7) |
| RTHA | 0.09 (0.4) | 0.21 (0.5) | 0.06 (0.2) | 0.22 (0.5) | 0.14 (0.3) | 0.19 (0.5) |
| GOEA | 0.07 (0.3) | 0.08 (0.3) | 0.16 (0.4) | 0.17 (0.4) | 0.29 (0.5) | 0.13 (0.4) |
| SWHA | 0.06 (0.2) | 0.12 (0.4) | 0.09 (0.3) | 0.11 (0.4) | 0.17 (0.5) | 0.25 (1.0) |
| FEHA | 0.07 (0.3) | 0.08 (0.3) | 0.10 (0.3) | 0.08 (0.3) | 0.14 (0.4) | 0.06 (0.3) |
| SEOW | 0.03 (0.2) | 0.02 (0.1) | 0.01 (0.1) | 0.02 (0.2) | 0.05 (0.2) | 0.10 (0.4) |
| RLHA | 0.01 (0.1) | 0.01 (0.1) | 0.10 (0.3) | 0.03 (0.2) | 0.09 (0.3) | 0.03 (0.2) |
| AMKE | 0.01 (0.1) | 0.04 (0.2) | 0.04 (0.3) | 0.02 (0.1) | -- | 0.02 (0.1) |
| BUOW | -- | 0.02 (0.2) | -- | -- | -- | 0.02 (0.1) |
| TUVU | -- | 0.02 (0.1) | -- | -- | -- | 0.03 (0.3) |
| COHA | 0.01 (0.1) | -- | -- | 0.01 (0.1) | -- | -- |
| SSHA | -- | -- | -- | 0.01 (0.1) | -- | -- |
| UNID | 0.01 (0.1) | 0.13 (0.4) | 0.13 (0.5) | 0.14 (0.4) | 0.18 (0.5) | 0.07 (0.3) |

Table 7. Point counts means and standard deviations (SD) for 32 pairs of sites on days of "military training" and days of "no military training." All means are detections per count.

| | Military Training | | No Military Training | |
|---|---|---|---|---|
| | OTA Mean (SD) N = 34 | Non-OTA Mean (SD) N = 34 | OTA Mean (SD) N = 57 | Non-OTA Mean (SD) N = 57 |
| All Birds | 5.11 (5.6) | 4.74 (6.9) | 2.86 (2.7) | 4.23 (3.7) |
| Raptors | 2.00 (2.4) | 1.85 (1.7) | 1.11 (1.4) | 1.65 (1.6) |
| Ravens | 3.12 (5.2) | 2.88 (6.5) | 1.75 (2.5) | 2.58 (3.1) |

**Raptor and Raven Detections -- OTA vs. Off-OTA**

The mean of 4.1 birds per count for all raptors and ravens was the same for both OTA and off-OTA points (Table 3). The mean count for raptors (excluding ravens) was very slightly higher off the OTA than on. Sightings of red-tailed hawks, northern harriers, Swainson's hawks, short-eared owls (*Asio flammeus*), and American kestrels (*Falco sparverius*) tended to be higher outside the OTA than inside, but the numbers of sightings were small and the differences slight. Conversely, slightly more ravens, rough-legged hawks (*Buteo lagopus*), prairie falcons, golden eagles, and ferruginous hawks were seen inside the OTA than outside.

Diurnal differences.--Several species showed small differences between OTA and off-OTA numbers during different diurnal periods for all ISA points (Table 6). In general, we recorded more sightings of raptors and ravens combined inside the OTA than outside in the morning and evening, and more sightings outside the OTA in the afternoon. Ravens followed a similar diurnal pattern, while raptors alone were seen more outside the OTA in the morning and afternoon, and more inside the OTA in the evening.

Training vs. no training.--We saw slightly more birds inside the OTA than outside on days of military training (Table 7). On days on which no military training occurred, more raptor detections were recorded outside the OTA.

Within the OTA, higher numbers of raptors and ravens were seen in the OTA on "training" days (4.97 birds/count) than on "no training" days (3.34 birds/count).

**Observer Variability**

There was little variation among any of the 3 observers for numbers of raptors and ravens combined or for numbers of raptors only. The largest difference appeared between 2 of the observers for numbers of ravens (2.3 birds/count compared with 3.2 birds/count). Ravens are the most difficult species to count in the field because of their tendency to flock; when a large flock is present at a site, it is difficult to distinguish individuals and some birds may be missed, or may be recounted. The variation between observers may be a result of 1 observer's tendency to over- or underestimate the size of raven flocks.

## PLANS FOR NEXT YEAR

We will continue to conduct point counts 3 times at each of 190 sites during each of 3 seasons. We will also investigate the efficacy of increasing the length of each point count in order to reduce the number of zero counts.

As soon as a revised vegetation map is available, the vegetation of all sample sites will be described by the GIS, and similarity indexes will be calculated and field-tested. If the similarity indices prove to be reasonably accurate, new pairings will be established for pairs with similarity values of 80% or greater.

Appropriate models of analysis will be sought and applied to 1991 and 1992 data.

## ACKNOWLEDGMENTS

We thank the Idaho Army National Guard (IDARNG) for making this research

possible, and Maj. Kurt Von Tagen, Capt. Tim Kelly, and MSgt. Mike Loosli of IDARNG Range Control for providing us with escorts into the Impact Area, and for making military training information available to us. Special thanks go to Ellen Clark for her able and untiring assistance in the field, and to Stephanie Gossett of the Raptor Research Center at BSU for administrative support. Steve Knick of the BLM, John Rotenberry of the Integration Team, and John Marzluff of Greenfalk Consultants provided invaluable advice on study design and statistics. Steve also donated many hours of labor in calculating similarity indices for us, helping us to get into the field much sooner than we would have otherwise. Deanna Dyer and Tom Zarriello of the BLM helped us through an arduous site-selection process, and the BLM's Gerry Griggs has been instrumental in keeping the logistics of the study running smoothly. The BLM made our fieldwork possible by providing us with vehicles. We thank Tom Cade, John Rotenberry, Steve Knick, John Marzluff, Brian Maurer, Mike Kochert, and Karen Steenhof for comments and advice on this manuscript, and for their input at the 1991 Integration Workshop, along with Mike Collopy, Graham Smith, Mark Fuller, Dana Quinney, and Marjorie Blew.

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Watson, C.R.B., and K. Strickler. 1991. Raptor distribution and use of the Orchard Training Area and adjacent areas. In Research Plan to Assess the Impacts of Habitat Alteration in the Snake River Birds of Prey Area. U.S. Dep. Inter., Bur. Land Manage., Boise, Id.

Appendix A. Habitat Data Form.

Point Count Site # Zone: Date:

7.5 min Quad Map Name: Section: T: R:

Geographic Location: UTM: Lat: Long:

Road Directions:

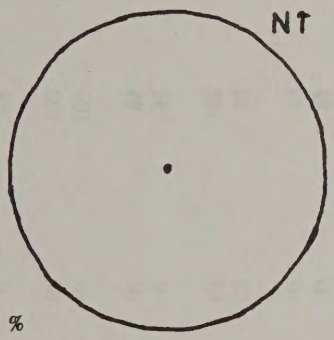
Walking Directions:

Elevation: Distance to Canyon:

General Slope Direction: # of Roads w/in 1km Radius:

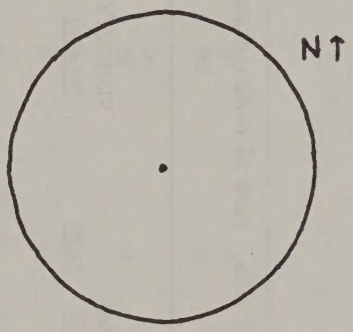
**VEGETATION / VISIBILITY CHARACTERISTICS**

Heterogeneity
Category:




Visibility

| Direction | Stops | Starts |
|---|---|---|
| 16° N | | |
| 61° NE | | |
| 106° E | | |
| 151° SE | | |
| 196° S | | |
| 241° SW | | |
| 286° W | | |
| 331° NW | | |




| Veg. type | % |
|---|---|
| | |
| | |
| | |

UNIQUE ATTRIBUTES

| | | | | Print # | Film # |
|---|---|---|---|---|---|
| Fences: | Direction | Length | Distance from Center | N - | |
| | | | | E - | |
| | | | | S - | |
| | | | | W - | |

Powerlines: Direction Length Distance from Center
Type:

Rocky Outcrops: Ht - <2m, 2-20m, >20m : D - <15m, 15-50m, >50m
Height Diameter Distance from Center

Other: NEST LOCATIONS:

Appendix B. Habitat and unique attribute summaries for 32 pairs of sites. Pairs of rows indicate pairs of matched sites. Point numbers beginning with "O" indicate OTA sites.

| POINT | NW/SE UNIT | HABITAT TYPE (percent)[a] ARTR | CHRY | CELA | ATCO | GRASS/ EXAN | AGRI | VISIBILITY (percent) | HETERO-GENEITY[b] | POWER LINE | FENCE | ROCK OUTCROP (number) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A4 | NW | 15 | 15 | 0 | 0 | 60 | 10 | 95 | 2 | No | Yes | 0 |
| 0A2 | NW | 30 | 0 | 0 | 0 | 70 | 0 | 91 | 1 | No | No | 3 |
| A5 | NW | 40 | 0 | 0 | 0 | 60 | 0 | 85 | 1 | No | Yes | 0 |
| 0A9 | NW | 40 | 0 | 0 | 0 | 60 | 0 | 88 | 1 | No | No | 16 |
| A6 | NW | 0 | 0 | 0 | 0 | 100 | 0 | 97 | 1 | No | No | 1 |
| OA10 | NW | 0 | 0 | 0 | 0 | 100 | 0 | 98 | 1 | No | No | 4 |
| B2 | NW | 15 | 10 | 0 | 0 | 70 | 5 | 88 | 3 | Yes | No | 4 |
| OB2 | NW | 20 | 0 | 0 | 0 | 80 | 0 | 95 | 1 | No | No | 1 |
| B5 | NW | 10 | 0 | 0 | 0 | 85 | 5 | 86 | 1 | Yes | Yes | 1 |
| OB21 | NW | 20 | 0 | 0 | 0 | 80 | 0 | 85 | 1 | No | Yes | 12 |
| B7 | NW | 90 | 0 | 0 | 0 | 10 | 0 | 83 | 1 | Yes | No | 1 |
| OB3 | NW | 90 | 0 | 0 | 0 | 10 | 0 | 72 | 1 | No | No | 0 |
| B9 | NW | 75 | 0 | 0 | 0 | 25 | 0 | 94 | 1 | No | No | 0 |
| OB8 | NW | 75 | 0 | 0 | 0 | 25 | 0 | 96 | 1 | No | No | 0 |
| B13 | NW | 70 | 0 | 0 | 0 | 30 | 0 | 86 | 1 | No | No | 0 |
| OB20 | NW | 60 | 0 | 0 | 0 | 40 | 0 | 76 | 1 | No | No | 12 |
| B16 | NW | 20 | 20 | 0 | 0 | 60 | 0 | 89 | 3 | No | Yes | 0 |
| OB9 | NW | 50 | 0 | 0 | 0 | 50 | 0 | 89 | 2 | No | No | 0 |
| B20 | NW | 0 | 0 | 0 | 0 | 90 | 10 | 90 | 1 | Yes | Yes | 12 |
| OB1 | NW | 1 | 1 | 0 | 0 | 98 | 0 | 87 | 1 | No | No | 4 |
| C4 | NW | 70 | 0 | 0 | 0 | 30 | 0 | 97 | 1 | No | No | 8 |
| OC4 | NW | 60 | 0 | 0 | 0 | 40 | 0 | 95 | 1 | No | No | 4 |
| C16 | NW | 0 | 0 | 0 | 0 | 100 | 0 | 100 | 1 | Yes | No | 0 |
| OC1 | NW | 0 | 0 | 0 | 0 | 100 | 0 | 100 | 1 | No | Yes | 0 |
| C26 | NW | 10 | 0 | 50 | 40 | 0 | 0 | 89 | 2 | Yes | No | 0 |
| OC7 | NW | 0 | 0 | 50 | 50 | 0 | 0 | 78 | 1 | No | No | 0 |
| C27 | NW | 20 | 0 | 80 | 0 | 0 | 0 | 88 | 1 | No | No | 0 |
| OC3 | NW | 0 | 0 | 60 | 40 | 0 | 0 | 97 | 1 | No | No | 2 |

Appendix B. (continued)

| POINT | NW/SE UNIT | HABITAT TYPE (percent)[a] ARTR | CHRY | CELA | ATCO | GRASS/ EXAN | AGRI | VISIBILITY (percent) | HETERO-GENEITY[b] | POWER LINE | FENCE | ROCK OUTCROP (number) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C28 | NW | 0 | 0 | 0 | 100 | 0 | 0 | 78 | 1 | Yes | No | 0 |
| OC5 | NW | 10 | 0 | 0 | 90 | 0 | 0 | 90 | 1 | No | No | 0 |
| D12 | SE | 20 | 10 | 0 | 0 | 70 | 0 | 95 | 3 | No | No | 0 |
| OD6 | SE | 40 | 0 | 0 | 0 | 60 | 0 | 94 | 1 | No | No | 3 |
| D16 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 100 | 1 | Yes | No | 0 |
| OD2 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 95 | 1 | No | No | 8 |
| D18 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 74 | 1 | No | Yes | 0 |
| OD3 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 84 | 1 | No | No | 2 |
| D19 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 77 | 1 | No | Yes | 0 |
| OD5 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 87 | 1 | No | No | 8 |
| D21 | SE | 20 | 0 | 0 | 0 | 80 | 0 | 80 | 1 | Yes | Yes | 0 |
| OD1 | SE | 30 | 0 | 0 | 0 | 70 | 0 | 88 | 1 | No | No | 9 |
| E2 | SE | 75 | 0 | 0 | 0 | 25 | 0 | 75 | 2 | No | No | 2 |
| OE11 | SE | 70 | 0 | 0 | 0 | 30 | 0 | 92 | 1 | No | No | 1 |
| E3 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 89 | 1 | Yes | No | 0 |
| OE2 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 93 | 1 | No | No | 1 |
| E4 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 84 | 1 | No | No | 4 |
| OE1 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 86 | 1 | No | No | 6 |
| E6 | SE | 50 | 0 | 0 | 0 | 50 | 0 | 80 | 1 | No | No | 1 |
| OE12 | SE | 30 | 0 | 0 | 0 | 70 | 0 | 85 | 1 | No | Yes | 4 |
| E7 | SE | 5 | 5 | 0 | 45 | 45 | 0 | 94 | 1 | Yes | Yes | 0 |
| OE19 | SE | 10 | 0 | 0 | 45 | 45 | 0 | 91 | 1 | No | No | 20 |
| E8 | SE | 0 | 5 | 0 | 0 | 95 | 0 | 89 | 1 | Yes | Yes | 0 |
| OE3 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 74 | 1 | No | No | 3 |
| E9 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 79 | 1 | No | Yes | 0 |
| OE9 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 98 | 1 | No | Yes | 16 |
| E10 | SE | 25 | 0 | 0 | 0 | 75 | 0 | 92 | 1 | Yes | No | 0 |
| OE5 | SE | 30 | 0 | 0 | 0 | 70 | 0 | 90 | 1 | No | Yes | 15 |
| E11 | SE | 10 | 0 | 0 | 0 | 90 | 0 | 100 | 1 | Yes | Yes | 0 |
| OE7 | SE | 10 | 0 | 0 | 0 | 90 | 0 | 92 | 1 | No | No | 3 |

Appendix B. (continued)

| POINT | NW/SE UNIT | HABITAT TYPE (percent)[a] ARTR | CHRY | CELA | ATCO | GRASS/ EXAN | AGRI | VISIBILITY (percent) | HETERO-GENEITY[b] | POWER LINE | FENCE | ROCK OUTCROP (number) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E15 | SE | 2 | 0 | 0 | 0 | 98 | 0 | 96 | 1 | Yes | No | 0 |
| OE4 | SE | 5 | 0 | 0 | 0 | 95 | 0 | 88 | 1 | No | No | 0 |
| F7 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 93 | 1 | No | No | 14 |
| OF9 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 85 | 1 | No | No | 11 |
| F16 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 92 | 1 | No | No | 3 |
| OF10 | SE | 0 | 0 | 0 | 0 | 100 | 0 | 80 | 1 | No | No | 17 |

[a] Habitat codes: ARTR = big sagebrush (may also include bud sage or spiny hop sage); CHRY = rabbitbrush; CELA = winterfat; ATCO = shadscale; GRASS/EXAN = perennial grasses and/or exotic annuals; AGRI = agriculture.

[b] Heterogeneity codes: 1 = 1-2 habitat types; 2 = 3-5 habitat types, large patches; 3 = 3-5 habitat types, small patches; 4 = > 5 habitat types, large patches; 5 = > 5 habitat types, small patches.

OBS. PT. #: DAILY OBS. #: DATE: DAY PERIOD: TIME START:
PAIR PT. #: GROUP: SEASON: OBSERVER: TIME END:

**WEATHER** WIND DIR: WIND VEL: TEMP: BAR PRESS: SKY COVER:

**LIVESTOCK** TYPE: #: WATERHOLE DISTANCE: ACTIVE PREY TYPE: PREDATOR TYPE:

**MILITARY ACTIVITY** TIME: TYPE: LOCATION: DISTANCE:

| Species | # | Time 1st ob | App.dist. | Hab. over | S. act/alt | C. act | Comments | Aud. |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
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OBS. PT. #: DAILY OBS. #: DATE: DAY PERIOD: TIME START:
PAIR PT. #: GROUP: SEASON: OBSERVER: TIME END:

**WEATHER** WIND DIR: WIND VEL: TEMP: BAR PRESS: SKY COVER:

**LIVESTOCK** TYPE: #: WATERHOLE DISTANCE: ACTIVE PREY TYPE: PREDATOR TYPE:

**MILITARY ACTIVITY** TIME: TYPE: LOCATION: DISTANCE:

| Species | # | Time 1st ob | App.dist. | Hab. over | S. act/alt | C. act | Comments | Aud. |
|---|---|---|---|---|---|---|---|---|
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# Preliminary Report on the Habitat Relationships of the Townsend's Ground Squirrel (*Spermophilus townsendii*)

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*Annual Summary*

*During the first field season, January through June, of a planned 4-yr study, we developed methodology and initiated data collection for a study of the demography and habitat relationships of Townsend's ground squirrels (Spermophilus townsendii). The central thrust of the study is a livetrap effort conducted on 10 site pairs to determine the effect of wildfire and tracking by armored vehicles on ground squirrel density, survival, and reproduction. Both adult and juvenile densities were significantly higher on sites that had been tracked or burned, although the relationship did not always hold for individual sites. Productivity (juveniles/female) varied in an inconsistent fashion among burned and undisturbed sites. Adult weights were lowest on the native winterfat (Ceratoides lanata) sites, on 2 sagebrush (Artemisia tridentata) sites inside the Orchard Training Area (OTA), on 1 burned sagebrush site inside the OTA, and on 2 burned winterfat sites outside the OTA. Juveniles had a lower mass on 1 of the burned winterfat sites outside the OTA, 1 of the winterfat sites outside the OTA, and 1 of the sagebrush sites inside the OTA, probably because they were born 20 to 30 days later on these sites. There was a positive relationship between hole density and squirrel density across sites, although this was significant only for shrubby sites. We estimated up to 127 apparently active holes per squirrel, although on 18 of the 20 sites we estimated less than 22 active holes per squirrel. Holes became undetectable fairly rapidly after the squirrels stopped above-ground activity during the late May to early July period.*

## OBJECTIVES

1. To make significant progress toward the goals of determining whether Townsend's ground squirrel (*Spermophilus townsendii*) densities, survival rates, and productivity differ:

   a) among habitat types.
   b) between areas that have been subjected to tracked vehicle operations over a long period of time and those that have not.
   c) between burned and unburned areas.
   d) between burned areas that have been seeded and those that have not been seeded.

2. To determine whether *S. townsendii* diets differ among sexes, age classes, or sites.

3. To describe vegetation coverage and structure on each site to aid in the interpretation of demographic, dietary, and behavioral differences among *S. townsendii* from different sites.

## METHODS

We located 10 pairs of 10-ha sites (Table 1; Fig. 1) in mid-January and covered each site with a grid of fencepost markers spaced at 75-m intervals. Beginning at the center of each site and moving outward in an expanding square, we identified and numbered consecutively 100 apparently active *S. townsendii* holes in early February. Active holes had tracks or evidence of fresh digging activity, and did not have tail-drags or enter the ground at a very low angle as is characteristic of *Dipodomys ordii* or *Dipodomys microps*. Hole locations were recorded with a bearing and distance to the nearest grid stake, and were marked with an aluminum tag that was nailed into the ground. The outer perimeter of the area containing 100 holes became the trapping area on each site. Where numbers of captures were very low, this trapping area was expanded following the first trapping cycle to a maximum of 10 ha.

Each site was trapped for 2 (9 sites), 3 (10 sites), or 4 (1 site) trapping cycles during the February-June period (Table 2). Because the squirrels showed a greater sensitivity to bad weather than we had anticipated, and because the spring was unusually cold and rainy, we were unable to trap all sites for 3 cycles. The squirrels did not become active above ground at certain times, probably when the combination of wind, solar radiation, air temperature, and surface temperature was unfavorable. We omitted the third trapping cycle on sites that had very low densities or had been trapped most recently.

During each cycle, each site was livetrapped by 2 technicians for 2 to 12 days, until there were fewer than 3 untagged adults being captured, or for 4 days during the period of juvenile emergence, for a total of 514 person-days. During the phase of juvenile emergence on sites with high juvenile densities we were still catching large numbers of unmarked juveniles on our final day of trapping within a cycle. Trapping was done for up to 3 sessions per day, depending on weather and ground squirrel activity, for a total of 19,329 trap sets.

Table 1. Site pairs established in January of 1991 for sampling of *Spermophilus townsendii*.

| Habitat type | Designators |
|---|---|
| Winterfat outside the Orchard Training Area (OTA) | 1a, 1b |
| Sagebrush outside the OTA | 2a, 2b |
| Shadscale outside the OTA | 3a, 3b |
| Burned Sagebrush inside the OTA | 4a, 4b |
| Sagebrush inside the OTA | 5a, 5b |
| Burned Winterfat outside the OTA | 6a, 6b |
| Burned Sagebrush outside the OTA | 7a, 7b |
| Burned and Seeded Winterfat outside the OTA | 8a, 8b |
| Sagebrush inside the OTA that will be tracked in 1992 | 9a, 9b |
| Burned Sagebrush inside the OTA that will be tracked in 1992 | 10a, 10b |

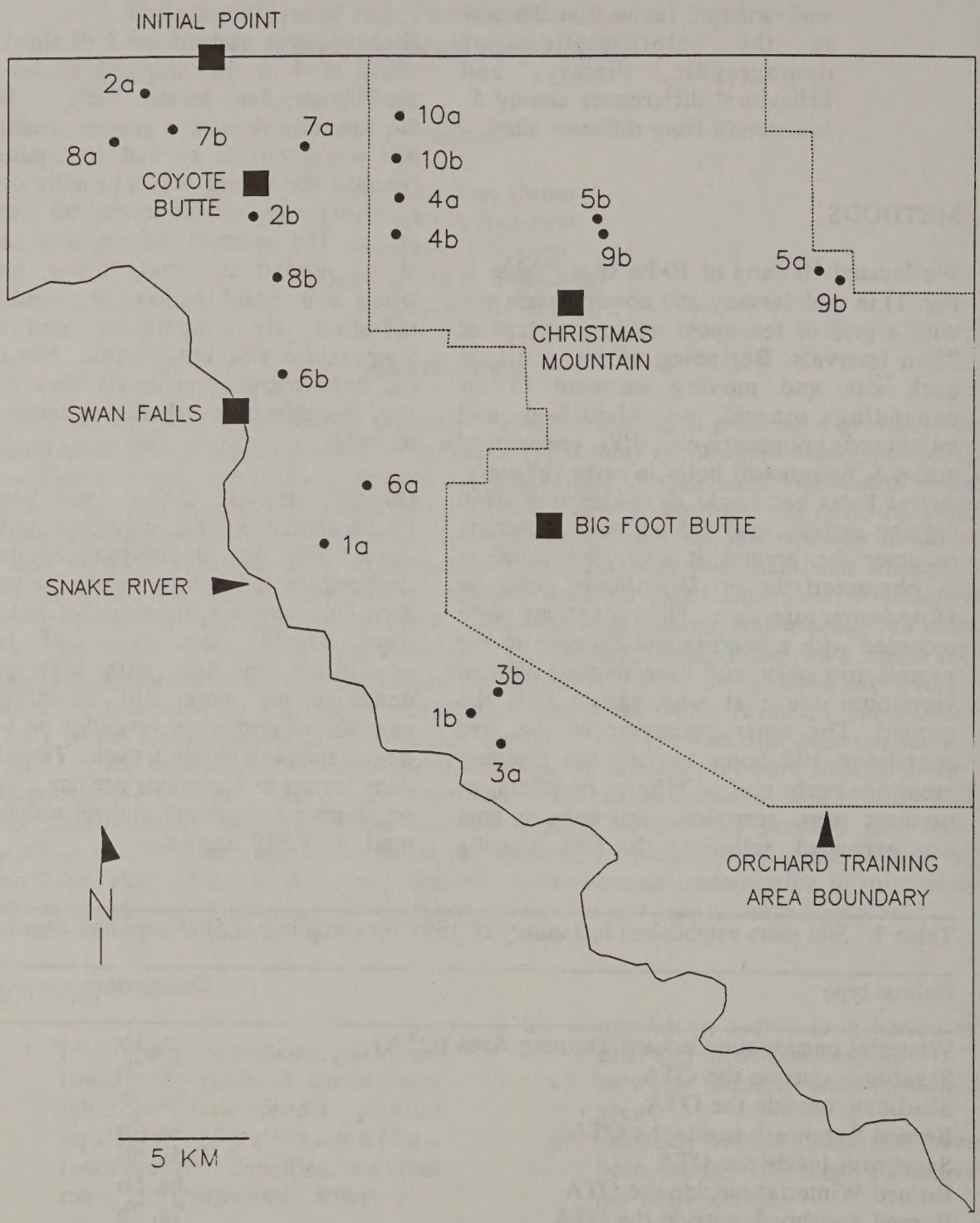


Fig. 1. Map of a portion of the Snake River Birds of Prey Area (SRBOPA) near Boise, Idaho, showing study site locations (see Table 1 for site types).

Table 2. Trapping dates for *Spermophilus townsendii*, 1991. Number of occasions (days in which at least 1 animal was trapped) is in parentheses.

| Site | Cycle 1 | Cycle 2 | Cycle 3 |
|---|---|---|---|
| 1a | 26 FEB - 9 MAR ( 9) | 13 APR - 18 APR (4) | 12 MAY- 19 MAY (4)[a] |
| 1b | 12 MAR- 18 MAR ( 5) | 21 APR - 4 MAY (4) | 25 JUN - 26 JUN (2) |
| 2a | 19 FEB - 9 MAR (12) | 13 APR - 18 APR (4) | |
| 2b | 13 MAR- 18 MAR ( 2) | 6 MAY - 16 MAY(4) | |
| 3a | 27 MAR- 31 MAR ( 0) | 7 MAY - 21 MAY(1) | |
| 3b | 3 APR - 8 APR ( 4) | 5 MAY - 21 MAY(5) | |
| 4a | 23 MAR- 28 MAR ( 4) | 30 APR - 5 MAY (4) | 27 JUN - 28 JUN (2) |
| 4b | 2 APR - 7 APR ( 5) | 6 MAY - 16 MAY(5) | 19 JUN - 21 JUN (3) |
| 5a | 12 MAR- 18 MAR ( 6) | 20 APR - 23 APR (4) | |
| 5b | 26 FEB - 9 MAR (10) | 8 APR - 18 APR (5) | 22 MAY- 27 MAY (4) |
| 6a | 12 MAR- 18 MAR ( 1) | 6 MAY - 7 MAY (1) | |
| 6b | 23 MAR- 28 MAR ( 4) | 20 APR - 23 APR (4) | |
| 7a | 2 APR - 7 APR ( 5) | 28 APR - 5 MAY (5) | 26 MAY-29 MAY (4) |
| 7b | 16 FEB - 7 MAR ( 9) | 13 APR - 18 APR (4) | 27 MAY-29 MAY (3) |
| 8a | 23 MAR- 28 MAR ( 4) | 20 APR - 23 APR (4) | 19 MAY-22 MAY (4) |
| 8b | 2 APR - 5 APR ( 4) | 28 APR - 5 MAY (5) | 20 MAY-26 MAY (4) |
| 9a | 31 MAR- 5 APR ( 6) | 5 MAY - 16 MAY(6) | |
| 9b | 23 MAR- 28 MAR ( 4) | 28 APR - 4 MAY (5) | |
| 10a | 26 FEB - 9 MAR ( 9) | 13 APR - 18 APR (4) | 19 MAY-22 MAY (4) |
| 10b | 12 MAR- 18 MAR ( 6) | 21 APR - 28 APR (4) | 25 MAY-28 MAY (4) |

[a] Site 1a was also trapped in Cycle 4, 22 JUN - 24 JUN (3)

During the second or second and third cycles, on each site where densities were not close to zero, assessment lines (Swift and Steinhorst 1976, Van Horne 1982) were trapped to estimate the rate of decline of the ratio of marked to unmarked animals with increasing distance from the trapping area, which could then be used to estimate the effective trapped area (i.e., adjust for edge effect) in the calculation of absolute density estimates. We used 4 lines of 10 traps each with 20-m spacing extending outward and centered perpendicular to each edge of each trapping site.

We used single-door, wire-mesh collapsible live traps (Tomahawk #201). On each occasion, traps were set when ground squirrels appeared to be active, baited with fresh apple, and checked within 2 hr. The number of traps used varied, depending on trap success, and was determined by the number a given team estimated they could check within 2 hr. Traps were located at numbered holes on each occasion using a stratified random procedure. Each trapping area was divided into 4 equal-sized sub-areas. Traps were allocated proportionately to sub-areas according to the number of holes in that sub-area, and placed at holes randomly selected by a computer program. They were moved every 2 days to new random locations within each sub-area. Squirrels were marked at initial capture by

injecting a uniquely-numbered Passive Integrated Transponder (PIT; Model TX 1400, Destron IDI) subcutaneously just posterior to the cranium, weighed to the nearest gram with a spring scale, dyed with a commercially available hair dye (Lady Clairol, Nice-n-Easy®), and their sex, age (adult or juvenile), and reproductive status (male testes scrotal or nonscrotal; females pregnant, lactating, or post-lactation) noted. Recaptured squirrels were uniquely identified using a portable reader (Model HS 5105, Destron IDI, Boulder CO), weighed, re-dyed if the dye had faded or been lost through molting, and reproductive status noted. Dye marks indicated sex and age, and were used to test for tag loss and to help with animal identification in the behavioral study.

Population size was estimated from the mark-recapture data using the recently updated version of program CAPTURE (Rexstad and Burnham 1991). For each data set (i.e., line) represented in Table 3 we entered the capture history matrix (as described in Otis et al. 1978) into program CAPTURE which produced a computer file of output data summaries and model selection information. The files were very extensive (about 100 files of 3 to 8 pages each) so were never printed. Each output file was scrutinized by both Burnham and (Dr. Eric) Rexstad (who assisted with the analyses), and a model was selected based on the results and exercise of our judgement. The reported estimators come from the selected model for each case. The models most commonly selected were $M_h$ (wherein the jackknife estimator was used) and $M_{th}$ (wherein we used a new estimator of Chao et al. 1992). We may change the estimators used for our final calculations, but we do not expect this to change materially estimates reported here.

Density as animals/ha was then estimated using an edge effect correction based on site- and age-specific assessment line data. We are still in the process of refining these calculations as well, but for this report we have used an estimator based on line transect theory (Burnham et al. 1980) that is likely to provide a correction for edge effect that will be close to our final correction. For comparisons among sites, we used the maximum adult and juvenile densities estimated for any of the trapping cycles. These densities were compared across treatments (tracking, seeding, burn) using analysis of variance. Significance was evaluated at $\underline{P} < 0.05$ using Type III partial sums of squares (Proc GLM; SAS, SAS Institute Inc., Cary, North Carolina, USA). Two measures of productivity were estimated; the maximum number of juveniles/ha trapped during any trapping cycle, and the ratio of the maximum number of juveniles to the maximum number of adult females trapped during any cycle. Each of these measures was used in comparisons of productivity among sites.

We measured "survival" from cycle 1 to cycle 2 and from cycle 2 to cycle 3 on each site as the proportion of animals captured during a trapping cycle that was captured or known to be alive at the subsequent cycle. Sample sizes and numbers of trapping occasions were not adequate to calculate a more formal measure of survival. Animals not recaptured included those that had died; those that were present, but that we failed to recapture, perhaps because they had already immerged; and those that had dispersed.

Hole searches were conducted at the start of each trapping cycle so that all the active holes within the trapping area could be identified. Eighteen of 20 trapping areas were searched 3 times during the season (sites 6a and 3b were searched 2 times; these were sites with very low squirrel densities). During the first 2 weeks of June, holes in each trapping area were mapped

Table 3. Density calculations for *Spermophilus townsendii*.

| Site number | Trapping cycle | Area width (m) | Area length (m) | Size of trapped area (ha) | Hole count on the area | Strip width =D*K | M(t+1) # individuals captured | Naive density estimate, nhat/area | Integral calculated from assessment line | Estimated population size | Estimated density #/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Adult Males | | | | | | | | | | | |
| 1a | 1 | 118.47 | 118.91 | 1.41 | 101 | 68.53 | 4 | 3.55 | 121.16 | 5 | 1.61 |
| 1a | 2 | 125.48 | 123.88 | 1.55 | 136 | 59.74 | 2 | 1.29 | 121.16 | 2 | 0.63 |
| 1a | 3 | 125.48 | 123.88 | 1.55 | 136 | 59.74 | 2 | 1.29 | 121.16 | 2 | 0.63 |
| 1a | 4 | 118.47 | 118.91 | 1.41 | 101 | . | 0 | 0.00 | 121.16 | 0 | 0.00 |
| 1b | 1 | 150.84 | 151.39 | 2.28 | 100 | 63.57 | 2 | 0.88 | 121.16 | 2 | 0.46 |
| 1b | 2 | 150.78 | 151.34 | 2.28 | 104 | 63.52 | 2 | 0.88 | 121.16 | 2 | 0.46 |
| 1b | 3 | 150.78 | 151.34 | 2.28 | 104 | . | 0 | 0.00 | 121.16 | 0 | 0.00 |
| 2a | 1 | 219.28 | 241.26 | 5.29 | 100 | 46.42 | 3 | 0.57 | 65.61 | 3 | 0.40 |
| 2a | 2 | 238.31 | 241.12 | 5.75 | 106 | 46.32 | 2 | 0.35 | 65.61 | 2 | 0.25 |
| 2b | 1 | 217.44 | 199.59 | 4.34 | 103 | 45.07 | 1 | 0.23 | 65.61 | 1 | 0.16 |
| 2b | 2 | 222.54 | 211.35 | 4.70 | 122 | 45.85 | 1 | 0.21 | 65.61 | 1 | 0.15 |
| 3a | 1 | 137.29 | 49.80 | 2.06 | 100 | . | 0 | 0.00 | 121.16 | 0 | 0.00 |
| 3a | 2 | 320.81 | 296.73 | 9.52 | 208 | . | 0 | 0.00 | 121.16 | 0 | 0.00 |
| 3b | 1 | 134.94 | 129.07 | 1.74 | 100 | 60.06 | 1 | 0.57 | 121.16 | 1 | 0.28 |
| 3b | 2 | 134.92 | 129.04 | 1.74 | 102 | . | 0 | 0.00 | 121.16 | 0 | 0.00 |
| 4a | 1 | 42.51 | 42.32 | 0.18 | 100 | 40.12 | 5 | 27.79 | 121.16 | 5 | 9.20 |
| 4a | 2 | 85.35 | 84.12 | 0.72 | 201 | 52.68 | 4 | 5.57 | 121.16 | 4 | 2.42 |
| 4a | 3 | 85.35 | 84.12 | 0.72 | 201 | . | 0 | 0.00 | 121.16 | 0 | 0.00 |
| 4b | 1 | 60.49 | 2.03 | 0.38 | 100 | 46.55 | 6 | 15.99 | 121.16 | 6 | 6.14 |
| 4b | 2 | 101.92 | 99.63 | 1.02 | 200 | 56.04 | 6 | 5.91 | 121.16 | 6 | 2.73 |
| 4b | 3 | 101.92 | 99.63 | 1.02 | 200 | 55.34 | 1 | 0.98 | 121.16 | 1 | 0.45 |
| 5a | 1 | 112.15 | 116.29 | 1.30 | 100 | 38.68 | 10 | 7.67 | 65.61 | 10 | 4.52 |
| 5a | 2 | 111.75 | 117.45 | 1.31 | 157 | 38.73 | 8 | 6.10 | 65.61 | 8 | 3.60 |
| 5b | 1 | 141.47 | 136.08 | 1.93 | 109 | 45.00 | 14 | 8.31 | 65.61 | 16 | 4.99 |
| 5b | 2 | 141.18 | 135.40 | 1.91 | 241 | 43.29 | 12 | 6.80 | 65.61 | 13 | 4.14 |
| 5b | 3 | 141.18 | 135.40 | 1.91 | 241 | 54.32 | 4 | 3.14 | 65.61 | 6 | 1.73 |
| 6a | 1 | 139.99 | 139.73 | 1.96 | 100 | 62.85 | 1 | 0.51 | 121.16 | 1 | 0.27 |
| 6a | 2 | 139.99 | 139.73 | 1.96 | 100 | 62.85 | 1 | 0.51 | 121.16 | 1 | 0.27 |
| 6b | 1 | 71.16 | 82.07 | 0.58 | 100 | 50.49 | 3 | 5.14 | 121.16 | 3 | 2.14 |
| 6b | 2 | 105.29 | 106.96 | 1.13 | 200 | 57.11 | 4 | 3.55 | 121.16 | 4 | 1.67 |
| 7a | 1 | 132.19 | 124.06 | 1.64 | 100 | 60.91 | 6 | 3.66 | 121.16 | 6 | 1.84 |
| 7a | 2 | 148.46 | 156.29 | 2.32 | 221 | 64.50 | 7 | 3.02 | 121.16 | 7 | 1.61 |
| 7a | 3 | 148.46 | 156.29 | 2.32 | 221 | 64.32 | 6 | 2.59 | 121.16 | 6 | 1.37 |
| 7b | 1 | 49.91 | 71.41 | 0.36 | 100 | 45.81 | 8 | 22.44 | 121.16 | 8 | 8.49 |
| 7b | 2 | 61.30 | 77.15 | 0.47 | 144 | 48.58 | 5 | 10.57 | 121.16 | 5 | 4.24 |
| 7b | 3 | 61.30 | 77.15 | 0.47 | 144 | 48.52 | 2 | 4.23 | 121.16 | 2 | 1.69 |
| 8a | 1 | 79.24 | 86.82 | 0.69 | 108 | 52.21 | 5 | 7.27 | 121.16 | 5 | 3.13 |
| 8a | 2 | 82.05 | 86.44 | 0.71 | 205 | 52.45 | 4 | 5.64 | 121.16 | 4 | 2.44 |
| 8a | 3 | 82.05 | 86.44 | 0.71 | 205 | 52.40 | 3 | 4.23 | 121.16 | 3 | 1.83 |

Table 3. Continued.

| Site number | Trapping cycle | Area width (m) | Area length (m) | Size of trapped area (ha) | Hole count on the area | Strip width =D*K | M(t+1) # individuals captured | Naive density estimate, nhat/area | Integral calculated from assessment line | Estimated population size | Estimated density #/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 8b | 1 | 85.49 | 77.42 | 0.66 | 100 | 51.85 | 6 | 9.07 | 121.16 | 6 | 3.88 |
| 8b | 2 | 89.32 | 92.71 | 0.83 | 150 | 54.04 | 3 | 3.62 | 121.16 | 3 | 1.62 |
| 8b | 3 | 89.32 | 92.71 | 0.83 | 150 | 53.93 | 4 | 4.83 | 121.16 | 4 | 2.15 |
| 9a | 1 | 109.21 | 108.83 | 1.19 | 100 | 38.16 | 9 | 7.57 | 65.61 | 9 | 4.40 |
| 9a | 2 | 136.17 | 141.19 | 1.92 | 225 | 40.89 | 9 | 4.68 | 65.61 | 9 | 2.92 |
| 9b | 1 | 112.91 | 104.87 | 1.18 | 101 | 38.14 | 10 | 8.44 | 65.61 | 10 | 4.91 |
| 9b | 2 | 114.19 | 118.67 | 1.36 | 208 | 41.88 | 9 | 7.38 | 65.61 | 10 | 4.24 |
| 10a | 1 | 85.24 | 83.12 | 0.71 | 103 | 58.33 | 11 | 18.35 | 121.16 | 13 | 7.48 |
| 10a | 2 | 84.81 | 106.65 | 0.90 | 215 | 54.65 | 4 | 4.42 | 121.16 | 4 | 1.99 |
| 10a | 3 | 84.81 | 106.65 | 0.90 | 215 | 65.41 | 3 | 4.42 | 121.16 | 4 | 1.79 |
| 10b | 1 | 125.68 | 110.53 | 1.39 | 100 | 66.61 | 10 | 8.64 | 121.16 | 12 | 3.96 |
| 10b | 2 | 124.83 | 120.68 | 1.51 | 316 | 60.14 | 8 | 5.31 | 121.16 | 8 | 2.64 |
| 10b | 3 | 124.83 | 120.68 | 1.51 | 316 | 60.14 | 8 | 5.31 | 121.16 | 8 | 2.64 |
| Adult Females | | | | | | | | | | | |
| 1a | 1 | 118.47 | 118.91 | 1.41 | 101 | 48.52 | 5 | 4.26 | 74.51 | 6 | 2.31 |
| 1a | 2 | 125.48 | 123.88 | 1.55 | 136 | 43.29 | 4 | 2.57 | 74.51 | 4 | 1.49 |
| 1a | 3 | 125.48 | 123.88 | 1.55 | 136 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 1a | 4 | 125.48 | 123.88 | 1.55 | 136 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 1b | 1 | 150.84 | 151.39 | 2.28 | 100 | 45.75 | 3 | 1.31 | 74.51 | 3 | 0.81 |
| 1b | 2 | 150.78 | 151.34 | 2.28 | 104 | 45.79 | 2 | 0.88 | 74.51 | 2 | 0.54 |
| 1b | 3 | 150.78 | 151.34 | 2.28 | 104 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 2a | 1 | 219.28 | 241.26 | 5.29 | 100 | 37.51 | 2 | 0.38 | 50.15 | 2 | 0.28 |
| 2a | 2 | 238.31 | 241.12 | 5.75 | 106 | 37.23 | 2 | 0.35 | 50.15 | 2 | 0.26 |
| 2b | 1 | 217.44 | 199.59 | 4.34 | 103 | 36.35 | 1 | 0.23 | 50.15 | 1 | 0.17 |
| 2b | 2 | 222.54 | 211.35 | 4.70 | 122 | . | 0 | 0.00 | 50.15 | 0 | 0.00 |
| 3a | 1 | 137.29 | 149.80 | 2.06 | 100 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 3a | 2 | 320.81 | 296.73 | 9.52 | 208 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 3b | 1 | 134.94 | 129.07 | 1.74 | 100 | 44.12 | 3 | 1.72 | 74.51 | 3 | 1.02 |
| 3b | 2 | 134.92 | 129.04 | 1.74 | 102 | 44.10 | 3 | 1.72 | 74.51 | 3 | 1.02 |
| 4a | 1 | 42.51 | 42.32 | 0.18 | 100 | 33.88 | 9 | 61.15 | 74.51 | 11 | 22.75 |
| 4a | 2 | 85.35 | 84.12 | 0.72 | 201 | 38.43 | 9 | 12.54 | 74.51 | 9 | 6.47 |
| 4a | 3 | 85.35 | 84.12 | 0.72 | 201 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 4b | 1 | 60.49 | 62.03 | 0.38 | 100 | 36.52 | 10 | 29.32 | 74.51 | 11 | 13.06 |
| 4b | 2 | 101.92 | 99.63 | 1.02 | 200 | 40.67 | 10 | 9.85 | 74.51 | 10 | 5.38 |
| 4b | 3 | 101.92 | 99.63 | 1.02 | 200 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 5a | 1 | 112.15 | 116.29 | 1.30 | 100 | 31.90 | 7 | 5.37 | 50.15 | 7 | 3.41 |
| 5a | 2 | 111.75 | 117.45 | 1.31 | 157 | 31.95 | 8 | 6.10 | 50.15 | 8 | 3.88 |
| 5b | 1 | 141.47 | 136.08 | 1.93 | 109 | 33.58 | 14 | 7.27 | 50.15 | 14 | 4.87 |
| 5b | 2 | 141.18 | 135.40 | 1.91 | 241 | 34.92 | 18 | 9.94 | 50.15 | 19 | 6.56 |
| 5b | 3 | 141.18 | 135.40 | 1.91 | 241 | 33.45 | 5 | 2.62 | 50.15 | 5 | 1.74 |

Table 3. Continued.

| Site number | Trapping cycle | Area width (m) | Area length (m) | Size of trapped area (ha) | Hole count on the area | Strip width =D*K | M(t+1) # individuals captured | Naive density estimate, nhat/area | Integral calculated from assessment line | Estimated population size | Estimated density #/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6a | 1 | 139.99 | 139.73 | 1.96 | 100 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 6a | 2 | 139.99 | 139.73 | 1.96 | 100 | . | 0 | 0.00 | 74.51 | 0 | 0.00 |
| 6b | 1 | 71.16 | 82.07 | 0.58 | 100 | 40.50 | 7 | 13.70 | 74.51 | 8 | 6.51 |
| 6b | 2 | 105.29 | 106.96 | 1.13 | 200 | 41.35 | 6 | 5.33 | 74.51 | 6 | 2.96 |
| 7a | 1 | 132.19 | 124.06 | 1.64 | 100 | 47.25 | 26 | 17.68 | 74.51 | 29 | 10.05 |
| 7a | 2 | 148.46 | 156.29 | 2.32 | 221 | 49.83 | 17 | 8.19 | 74.51 | 19 | 4.90 |
| 7a | 3 | 148.46 | 156.29 | 2.32 | 221 | 66.60 | 10 | 7.33 | 74.51 | 17 | 3.85 |
| 7b | 1 | 49.91 | 71.41 | 0.36 | 100 | 33.87 | 7 | 19.64 | 74.51 | 7 | 8.93 |
| 7b | 2 | 61.30 | 77.15 | 0.47 | 144 | 35.73 | 5 | 10.57 | 74.51 | 5 | 5.07 |
| 7b | 3 | 61.30 | 77.15 | 0.47 | 144 | 35.72 | 1 | 2.11 | 74.51 | 1 | 1.01 |
| 8a | 1 | 79.24 | 86.82 | 0.69 | 108 | 42.59 | 11 | 18.90 | 74.51 | 13 | 9.14 |
| 8a | 2 | 82.05 | 86.44 | 0.71 | 205 | 38.36 | 9 | 12.69 | 74.51 | 9 | 6.53 |
| 8a | 3 | 82.05 | 86.44 | 0.71 | 205 | 38.38 | 6 | 8.46 | 74.51 | 6 | 4.36 |
| 8b | 1 | 85.49 | 77.42 | 0.66 | 100 | 37.91 | 12 | 18.13 | 74.51 | 12 | 9.22 |
| 8b | 2 | 89.32 | 92.71 | 0.83 | 150 | 39.37 | 10 | 12.08 | 74.51 | 10 | 6.38 |
| 8b | 3 | 89.32 | 92.71 | 0.83 | 150 | 39.34 | 8 | 9.66 | 74.51 | 8 | 5.10 |
| 9a | 1 | 109.21 | 108.83 | 1.19 | 100 | 31.52 | 13 | 10.94 | 50.15 | 13 | 6.87 |
| 9a | 2 | 136.17 | 141.19 | 1.92 | 225 | 33.52 | 6 | 3.12 | 50.15 | 6 | 2.09 |
| 9b | 1 | 112.91 | 104.87 | 1.18 | 101 | 31.49 | 9 | 7.60 | 50.15 | 9 | 4.77 |
| 9b | 2 | 114.19 | 118.67 | 1.36 | 208 | 47.21 | 11 | 14.02 | 50.15 | 19 | 7.64 |
| 10a | 1 | 85.24 | 83.12 | 0.71 | 103 | 38.37 | 17 | 24.00 | 74.51 | 17 | 12.36 |
| 10a | 2 | 84.81 | 106.65 | 0.90 | 215 | 43.14 | 16 | 19.90 | 74.51 | 18 | 10.24 |
| 10a | 3 | 84.81 | 106.65 | 0.90 | 215 | 39.87 | 12 | 13.27 | 74.51 | 12 | 7.10 |
| 10b | 1 | 125.68 | 110.53 | 1.39 | 100 | 45.10 | 12 | 9.36 | 74.51 | 13 | 5.23 |
| 10b | 2 | 124.83 | 120.68 | 1.51 | 316 | 51.40 | 14 | 11.95 | 74.51 | 18 | 6.41 |
| 10b | 3 | 124.83 | 120.68 | 1.51 | 316 | 46.52 | 9 | 6.64 | 74.51 | 10 | 3.73 |
| Juvenile Males | | | | | | | | | | | |
| 1a | 1 | 118.47 | 118.9 | 1.41 | 101 | . | . | . | . | . | . |
| 1a | 2 | 125.48 | 123.88 | 1.55 | 136 | 14.36 | 1 | 0.64 | 18.05 | 1 | 0.51 |
| 1a | 3 | 125.48 | 123.88 | 1.55 | 136 | 41.39 | 5 | 3.86 | 58.0 | 6 | 2.30 |
| 1a | 4 | 125.48 | 123.88 | 1.55 | 136 | 36.28 | 4 | 2.57 | 58.00 | 4 | 1.61 |
| 1b | 1 | 150.84 | 151.39 | 2.28 | 100 | . | . | . | . | . | . |
| 1b | 2 | 150.78 | 151.34 | 2.28 | 104 | 14.87 | 2 | 0.88 | 18.05 | 2 | 0.72 |
| 1b | 3 | 150.78 | 151.34 | 2.28 | 104 | 14.67 | 1 | 0.44 | 18.05 | 1 | 0.36 |
| 2a | 1 | 219.28 | 241.26 | 5.29 | 100 | . | . | . | . | . | . |
| 2a | 2 | 238.31 | 241.12 | 5.75 | 106 | 15.88 | 4 | 0.70 | 18.05 | 4 | 0.61 |
| 2b | 1 | 217.44 | 199.59 | 4.34 | 103 | . | . | . | . | . | . |
| 2b | 2 | 222.54 | 211.35 | 4.70 | 122 | 15.52 | 3 | 0.64 | 18.05 | 3 | 0.55 |
| 3a | 1 | 137.29 | 149.80 | 2.06 | 100 | . | . | . | . | . | . |
| 3a | 2 | 320.81 | 296.73 | 9.52 | 208 | . | . | . | 18.05 | . | . |
| 3b | 1 | 134.94 | 129.07 | 1.74 | 100 | . | . | . | . | . | . |
| 3b | 2 | 134.92 | 129.04 | 1.74 | 102 | 16.25 | 8 | 5.17 | 18.05 | 9 | 4.13 |

Table 3. Continued.

| Site number | Trapping cycle | Area width (m) | Area length (m) | Size of trapped area (ha) | Hole count on the area | Strip width =D*K | M(t+1) # individuals captured | Naive density estimate, nhat/area | Integral calculated from assessment line | Estimated population size | Estimated density #/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4a | 1 | 42.51 | 42.32 | 0.18 | 100 | . | . | . | . | . | . |
| 4a | 2 | 85.35 | 84.12 | 0.72 | 201 | 15.55 | 22 | 36.21 | 18.05 | 26 | 26.39 |
| 4a | 3 | 85.35 | 84.12 | 0.72 | 201 | 18.70 | 6 | 12.54 | 18.05 | 9 | 8.65 |
| 4b | 1 | 60.49 | 62.03 | 0.38 | 100 | 0.00 | 19 | 66.63 | 0.00 | 25 | 66.62 |
| 4b | 2 | 101.92 | 99.63 | 1.02 | 200 | 22.99 | 22 | 40.38 | 18.05 | 41 | 27.58 |
| 4b | 3 | 101.92 | 99.63 | 1.02 | 200 | 14.79 | 16 | 16.74 | 18.05 | 17 | 12.91 |
| 5a | 1 | 112.15 | 116.29 | 1.30 | 100 | . | . | . | . | . | . |
| 5a | 2 | 111.75 | 117.45 | 1.31 | 157 | 16.84 | 19 | 17.52 | 18.05 | 23 | 13.50 |
| 5b | 1 | 141.47 | 136.08 | 1.93 | 109 | . | . | . | . | . | . |
| 5b | 2 | 141.18 | 135.40 | 1.91 | 241 | 32.12 | 29 | 39.76 | 18.05 | 76 | 26.99 |
| 5b | 3 | 141.18 | 135.40 | 1.91 | 241 | 9.83 | 11 | 6.28 | 58.00 | 12 | 3.95 |
| 6a | 1 | 139.99 | 139.73 | 1.96 | 100 | . | . | . | . | . | . |
| 6a | 2 | 139.99 | 139.73 | 1.96 | 100 | . | 0 | 0.00 | 18.05 | 0 | 0.00 |
| 6b | 1 | 71.16 | 82.07 | 0.58 | 100 | . | . | . | . | . | . |
| 6b | 2 | 105.29 | 106.96 | 1.13 | 200 | 25.69 | 8 | 15.10 | 18.05 | 17 | 10.11 |
| 7a | 1 | 132.19 | 124.06 | 1.64 | 100 | 0.00 | 20 | 28.66 | 0.00 | 47 | 28.65 |
| 7a | 2 | 148.46 | 156.29 | 2.32 | 221 | 22.17 | 39 | 26.72 | 18.05 | 62 | 20.64 |
| 7a | 3 | 148.46 | 156.29 | 2.32 | 221 | 40.85 | 22 | 10.34 | 58.00 | 24 | 6.68 |
| 7b | 1 | 49.91 | 71.41 | 0.36 | 100 | . | . | . | . | . | . |
| 7b | 2 | 61.30 | 77.15 | 0.47 | 144 | 13.00 | 4 | 8.46 | 18.05 | 4 | 6.09 |
| 7b | 3 | 61.30 | 77.15 | 0.47 | 144 | 43.53 | 8 | 29.61 | 58.00 | 14 | 12.70 |
| 8a | 1 | 79.24 | 86.82 | 0.69 | 108 | . | . | . | . | . | . |
| 8a | 2 | 82.05 | 86.44 | 0.71 | 205 | 16.67 | 17 | 31.02 | 18.05 | 22 | 22.13 |
| 8a | 3 | 82.05 | 86.44 | 0.71 | 205 | 33.67 | 17 | 25.38 | 58.00 | 18 | 13.92 |
| 8b | 1 | 85.49 | 77.42 | 0.66 | 100 | . | . | . | . | . | . |
| 8b | 2 | 89.32 | 92.71 | 0.83 | 150 | 16.49 | 12 | 18.11 | 18.05 | 15 | 13.24 |
| 8b | 3 | 89.32 | 92.71 | 0.83 | 150 | 36.37 | 14 | 19.32 | 58.00 | 16 | 10.60 |
| 9a | 1 | 109.21 | 108.83 | 1.19 | 100 | 0.00 | 9 | 9.26 | 0.00 | 11 | 9.25 |
| 9a | 2 | 136.17 | 141.19 | 1.92 | 225 | 25.61 | 20 | 20.29 | 18.05 | 39 | 14.76 |
| 9b | 1 | 112.91 | 104.87 | 1.18 | 101 | . | . | . | . | . | . |
| 9b | 2 | 114.19 | 118.67 | 1.36 | 208 | 16.89 | 19 | 16.97 | 18.05 | 23 | 13.12 |
| 10a | 1 | 85.24 | 83.12 | 0.71 | 103 | . | . | . | . | . | . |
| 10a | 2 | 84.81 | 106.65 | 0.90 | 215 | 17.50 | 15 | 22.11 | 18.05 | 20 | 16.07 |
| 10a | 3 | 84.81 | 106.65 | 0.90 | 215 | 36.95 | 20 | 25.43 | 58.00 | 23 | 14.09 |
| 10b | 1 | 125.68 | 110.53 | 1.39 | 100 | . | . | . | . | . | . |
| 10b | 2 | 124.83 | 120.68 | 1.51 | 316 | 18.71 | 14 | 12.61 | 18.05 | 19 | 9.63 |
| 10b | 3 | 124.83 | 120.68 | 1.51 | 316 | 41.19 | 15 | 11.95 | 58.00 | 18 | 7.07 |
| Juvenile Females | | | | | | | | | | | |
| | 1 | 118.47 | 118.91 | 1.41 | 101 | . | . | . | . | . | . |
| 1a | 2 | 125.48 | 123.88 | 1.55 | 136 | 14.50 | 2 | 1.29 | 18.05 | 2 | 1.03 |
| 1a | 3 | 125.48 | 123.88 | 1.55 | 136 | 36.28 | 5 | 3.22 | 58.00 | 5 | 2.01 |
| 1a | 4 | 125.48 | 123.88 | 1.55 | 136 | 36.27 | 3 | 1.93 | 58.00 | 3 | 1.21 |

Table 3. Continued.

| Site number | Trapping cycle | Area width (m) | Area length (m) | Size of trapped area (ha) | Hole count on the area | Strip width =D*K | M(t+1) # individuals captured | Naive density estimate, nhat/area | Integral calculated from assessment line | Estimated population size | Estimated density #/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | 4 | 125.48 | 123.88 | 1.55 | 136 | 36.27 | 3 | 1.93 | 58.00 | 3 | 1.21 |
| 1b | 1 | 150.84 | 151.39 | 2.28 | 100 | . | . | . | . | . | . |
| 1b | 2 | 150.78 | 151.34 | 2.28 | 104 | 15.00 | 5 | 2.19 | 18.05 | 5 | 1.82 |
| 1b | 3 | 150.78 | 151.34 | 2.28 | 104 | 14.94 | 3 | 1.31 | 18.05 | 3 | 1.09 |
| 2a | 1 | 219.28 | 241.26 | 5.29 | 100 | . | . | . | . | . | . |
| 2a | 2 | 238.31 | 241.12 | 5.75 | 106 | 21.25 | 5 | 1.22 | 18.05 | 7 | 1.02 |
| 2b | 1 | 217.44 | 199.59 | 4.34 | 103 | . | . | . | . | . | . |
| 2b | 2 | 222.54 | 211.35 | 4.70 | 122 | 18.48 | 5 | 1.28 | 18.05 | 6 | 1.09 |
| 3a | 1 | 137.29 | 149.80 | 2.06 | 100 | . | . | . | . | . | . |
| 3a | 2 | 320.81 | 296.73 | 9.52 | 208 | . | . | . | 18.05 | . | . |
| 3b | 1 | 134.94 | 129.07 | 1.74 | 100 | . | . | . | . | . | . |
| 3b | 2 | 134.92 | 129.04 | 1.74 | 102 | 17.41 | 9 | 6.32 | 18.05 | 11 | 4.99 |
| 4a | 1 | 42.51 | 42.32 | 0.18 | 100 | . | . | . | . | . | . |
| 4a | 2 | 85.35 | 84.12 | 0.72 | 201 | 16.56 | 32 | 57.10 | 18.05 | 41 | 40.89 |
| 4a | 3 | 85.35 | 84.12 | 0.72 | 201 | 17.08 | 6 | 11.14 | 18.05 | 8 | 7.90 |
| 4b | 1 | 60.49 | 62.03 | 0.38 | 100 | 0.00 | 18 | 79.95 | 0.00 | 30 | 79.94 |
| 4b | 2 | 101.92 | 99.63 | 1.02 | 200 | 20.63 | 34 | 54.16 | 18.05 | 55 | 38.26 |
| 4b | 3 | 101.92 | 99.63 | 1.02 | 200 | 14.79 | 16 | 16.74 | 18.05 | 17 | 12.91 |
| 5a | 1 | 112.15 | 116.29 | 1.30 | 100 | . | . | . | . | . | . |
| 5a | 2 | 111.75 | 117.45 | 1.31 | 157 | 14.40 | 17 | 12.95 | 18.05 | 17 | 10.33 |
| 5b | 1 | 141.47 | 136.08 | 1.93 | 109 | . | . | . | . | . | . |
| 5b | 2 | 141.18 | 135.40 | 1.91 | 241 | 16.30 | 34 | 19.88 | 18.05 | 38 | 16.06 |
| 5b | 3 | 141.18 | 135.40 | 1.91 | 241 | 39.52 | 25 | 14.12 | 58.00 | 27 | 8.91 |
| 6a | 1 | 139.99 | 139.73 | 1.96 | 100 | . | . | . | . | . | . |
| 6a | 2 | 139.99 | 139.73 | 1.96 | 100 | . | 0 | 0.00 | 18.05 | 0 | 0.00 |
| 6b | 1 | 71.16 | 82.07 | 0.58 | 100 | . | . | . | . | . | . |
| 6b | 2 | 105.29 | 106.96 | 1.13 | 200 | 22.18 | 16 | 24.86 | 18.05 | 28 | 17.46 |
| 7a | 1 | 132.19 | 124.06 | 1.64 | 100 | 0.00 | 18 | 16.46 | 0.00 | 27 | 16.46 |
| 7a | 2 | 148.46 | 156.29 | 2.32 | 221 | 28.07 | 44 | 40.51 | 18.05 | 94 | 29.49 |
| 7a | 3 | 148.46 | 156.29 | 2.32 | 221 | 56.32 | 24 | 17.67 | 58.00 | 41 | 10.05 |
| 7b | 1 | 49.91 | 71.41 | 0.36 | 100 | . | . | . | . | . | . |
| 7b | 2 | 61.30 | 77.15 | 0.47 | 144 | 13.02 | 3 | 6.34 | 18.05 | 3 | 4.57 |
| 7b | 3 | 61.30 | 77.15 | 0.47 | 144 | 30.26 | 5 | 10.57 | 58.00 | 5 | 5.52 |
| 8a | 1 | 79.24 | 86.82 | 0.69 | 108 | . | . | . | . | . | . |
| 8a | 2 | 82.05 | 86.44 | 0.71 | 205 | 22.48 | 13 | 35.25 | 18.05 | 25 | 22.83 |
| 8a | 3 | 82.05 | 86.44 | 0.71 | 205 | 32.36 | 10 | 14.10 | 58.00 | 10 | 7.87 |
| 8b | 1 | 85.49 | 77.42 | 0.66 | 100 | . | . | . | . | . | . |
| 8b | 2 | 89.32 | 92.71 | 0.83 | 150 | 15.73 | 17 | 24.15 | 18.05 | 20 | 17.89 |
| 8b | 3 | 96.79 | 100.47 | 0.97 | 11 | 33.96 | 11 | 11.31 | 58.00 | 11 | 6.62 |
| 9a | 1 | 109.21 | 108.83 | 1.19 | 100 | 0.00 | 13 | 12.62 | 0.00 | 15 | 12.62 |
| 9a | 2 | 136.17 | 141.19 | 1.92 | 225 | 21.01 | 23 | 18.20 | 18.05 | 35 | 13.92 |
| 9b | 1 | 112.91 | 104.87 | 1.18 | 101 | . | . | . | . | . | . |
| 9b | 2 | 114.19 | 118.67 | 1.36 | 208 | 16.06 | 29 | 24.35 | 18.05 | 33 | 19.04 |

Table 3. Continued.

| Site number | Trapping cycle | Area width (m) | Area length (m) | Size of trapped area (ha) | Hole count on the area | Strip width =D*K | M(t+1) # individuals captured | Naive density estimate, nhat/area | Integral calculated from assessment line | Estimated population size | Estimated density #/ha |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10a | 1 | 85.24 | 83.12 | 0.71 | 103 | . | . | . | . | . | . |
| 10a | 2 | 84.81 | 106.65 | 0.90 | 215 | 22.95 | 40 | 84.03 | 18.05 | 76 | 56.23 |
| 10a | 3 | 84.81 | 106.65 | 0.90 | 215 | 42.98 | 32 | 50.86 | 58.00 | 46 | 26.22 |
| 10b | 1 | 125.68 | 110.53 | 1.39 | 100 | . | . | . | . | . | . |
| 10b | 2 | 124.83 | 120.68 | 1.51 | 316 | 16.38 | 33 | 25.23 | 18.05 | 38 | 19.87 |
| 10b | 3 | 124.83 | 120.68 | 1.51 | 316 | 45.70 | 23 | 21.24 | 58.00 | 32 | 12.03 |

using the entire crew and a single person, R.L. Schooley, as the arbiter whenever a designation as "active" or "inactive" or association with other species was questionable, so that inter-observer bias could be minimized and comparable estimates of hole density near the end of the active period could be obtained from each site. We estimate that 202 person-days, or about 20% of total person-days was spent marking and mapping holes. This does not include substantial time for data entry and management. Forty randomly-selected holes on each of sites 4a and 1b considered active in early June were re-surveyed by R.L. Schooley in late June and by 1 of our technicians (L. Kvaalen) in early August to determine whether they would continue to be classified as "active" when investigators were counting active *S. townsendii* holes during the transect survey study (Knick 1990). In the August survey, holes were designated as "active" or "inactive" using both criteria from our study and from the transect survey study. Criteria used in the latter study were more liberal (ie., they did not need to show evidence of recent activity) because most of the work was done after the *S. townsendii* had become inactive. One of the characteristics we used to distinguish holes of *Dipiodomys ordii* from those of *S. townsendii* was the presence of tail drags. If activity levels of the former species were lower during the time of the transect counts this would lead to an additional bias.

Information on plant types included in the diet was obtained from 455 fecal samples collected from known animals while the animals were being tagged. Samples were dried in a drying oven at 65 C for 48 hr shortly after collection, and were analyzed at the Composition Analysis Laboratory in Fort Collins, CO through comparison with a reference collection.

Vegetation was sampled twice on each site, during 14 March - 9 April and during 17 April-2 May (Table 4), by point intercept (Floyd and Anderson 1982). The sample unit consisted of a 3-m section in which we sampled species composition, frequency, canopy cover, and substrate. The number of transects with single 3-m sections needed to determine vegetation characteristics was assessed in the field by calculating a running mean of the 4 most abundant categories (Grieg-Smith 1983) and was standardized at 15. When shrubs were present, shrub density, maximum shrub height, mean shrub height from ground to canopy, and presence/absence of canopy was determined from 3.14 $m^2$ circular plots on 3 sites, and from 7.07 $m^2$ circular plots on 17 sites. Shrub plots were

Table 4. Timing of vegetation sampling.

| Site | Period 1 | Period 2 |
|---|---|---|
| 1a | 19 MAR | 17 APR |
| 1b | 30, 31 MAR | 24 APR |
| 2a | 30, 31 MAR | 18, 24 APR |
| 2b | 31 MAR | 2 MAY |
| 3a | 7, 9 APR | 2 MAY |
| 3b | 9 APR | 25 APR |
| 4a | 1, 3 APR | 24 APR |
| 4b | 6 APR | 2 MAY |
| 5a | 25, 30 MAR [a] | 24 APR |
| 5b | 24 MAR [a] | 17 APR |
| 6a | 31 MAR | 2 MAY |
| 6b | 30 MAR | 24 APR |
| 7a | 6 APR | 24, 25 APR |
| 7b | 14 MAR | 17 APR |
| 8a | 30 MAR | 24 APR |
| 8b | 6 APR | 25 APR |
| 9a | 6 APR | 2 MAY |
| 9b | 24, 25 MAR [a] | 24 APR |
| 10a | 24 MAR | 17 APR |
| 10b | 25 MAR | 24 APR |

[a] Shrub heights measured in 1.0-m radius, all other in 1.5-m radius.

established at each end of the 3-m sections for vegetation sampling by point frame.

## RESULTS

### Density, Productivity, and Survival

These results are preliminary and our conclusions are likely to change as we accumulate data over 3 additional years. A total of 1180 animals was marked in 4767 capture events. Effective trapped areas and densities varied among sites and cycles (Table 3). Lower adult densities during the last trapping cycle on each site are probably the effects of burning, tracking (inside or outside the OTA) and seeding on adult densities, juvenile densities, and number of juveniles per female. There were no significant interactions, seeding was never found to have a significant effect, and there were no significant effects on juveniles per female. We used a reduced model with only burning and tracking effects in separate tests with adult and juvenile densities as dependent variables. Burned sites had significantly higher adult and juvenile densities than unburned sites, and sites that had been tracked (inside OTA) had higher adult and juvenile densities than sites outside the OTA (Tables 5, 6, and 7).

Table 5. Site types (see Table 1), maximum densities, and sex ratios of *Spermophilus townsendii*.

| Site | Inside OTA | Burned | Seeded | Juvs/Fem | Adult Density #/ha | Proportion Adults Female | Juvenile Density #/ha | Proportion Juveniles Female |
|---|---|---|---|---|---|---|---|---|
| 1a | NO | NO | NO | 1.86 | 3.92 | 0.59 | 4.31 | 0.47 |
| 1b | | | | 3.15 | 1.27 | 0.64 | 2.54 | 0.72 |
| 2a | NO | NO | NO | 5.79 | 0.68 | 0.41 | 1.64 | 0.63 |
| 2b | | | | 9.80 | 0.33 | 0.51 | 1.64 | 0.66 |
| 3a | NO | NO | NO | ----- | 0.00 | ----- | 0.00 | ----- |
| 3b | | | | 8.94 | 1.30 | 0.78 | 9.12 | 0.55 |
| 4a | YES | YES | NO | 2.96 | 31.95 | 0.71 | 67.28 | 0.61 |
| 4b | | | | 11.22 | 19.21 | 0.68 | 146.57 | 0.55 |
| 5a | YES | NO | NO | 6.14 | 7.48 | 0.52 | 23.83 | 0.43 |
| 5b | | | | 6.57 | 10.70 | 0.61 | 43.05 | 0.37 |
| 6a | NO | YES | NO | ----- | 0.27 | 0.00 | 0.00 | ----- |
| 6b | | | | 4.23 | 8.65 | 0.75 | 27.57 | 0.63 |
| 7a | NO | YES | NO | 4.99 | 11.89 | 0.85 | 50.13 | 0.59 |
| 7b | | | | 2.04 | 17.41 | 0.51 | 18.21 | 0.30 |
| 8a | NO | YES | YES | 4.92 | 12.27 | 0.74 | 44.96 | 0.51 |
| 8b | | | | 3.37 | 13.10 | 0.70 | 31.12 | 0.57 |
| 9a | YES | NO | NO | 5.85 | 19.83 | 0.62 | 72.30 | 0.78 |
| 9b | | | | 4.21 | 11.88 | 0.64 | 32.16 | 0.59 |
| 10a | YES | YES | NO | 5.85 | 19.83 | 0.62 | 72.30 | 0.78 |
| 10b | | | | 4.60 | 9.05 | 0.71 | 29.50 | 0.67 |

Adult masses were lowest on sites 1a, 1b (winterfat), 6a, 6b (burned winterfat), 7b (burned sage), 8a, and 8b (burned and seeded winterfat; Fig. 2). Juveniles had a lower mass, probably because they were born 20 to 30 days later, on sites 1b, 6b, and 8b (none were captured on 6a; Fig. 2). Adult sex ratios were skewed toward females on all sites except sites 2a and 6a, where our sample size was too low for reliable conclusions (Table 5). Juvenile sex ratios also tended to be female-skewed, although

Table 6. Results of full and reduced model ANOVA's testing effects on an adult and juvenile *S. townsendii* density and number of juveniles per female of burning, seeding, and location inside or outside of the OTA.

| | Adult Density | | | | Juvenile Density | | | | Juveniles/Female | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | df | Sums of Squares | F | P | df | Sums of Squares | F | P | df | Sums of Squares | F | P |
| Full Model | | | | | | | | | | | | |
| Burned/Not Burned | 1 | 274 | 8.05 | 0.0125 | 1 | 3526 | 5.29 | 0.036 | 1 | 2.8 | 0.37 | 0.5509 |
| Inside/Outside OTA | 1 | 512 | 15.06 | 0.0015 | 1 | 9756 | 14.64 | 0.0017 | 1 | 4.6 | 0.63 | 0.4422 |
| Seeded/Not Seeded | 1 | 16 | 0.38 | 0.5476 | 1 | 264 | 0.40 | 0.5387 | 1 | 0.2 | 0.03 | 0.8762 |
| Burn * OTA | 1 | 1 | 0.02 | 0.8923 | 1 | 256 | 0.38 | 0.5449 | 1 | 6.7 | 0.90 | 0.3589 |
| Error | 15 | 34 | | | 15 | 666 | | | 13 | 7.0 | | |
| Reduced Model | | | | | | | | | | | | |
| Burned/Not Burned | 1 | 372 | 12 | 0.0030 | 1 | 4412 | 7.22 | 0.0156 | | | | |
| Inside/Outside OTA | 1 | 511 | 16 | 0.0008 | 1 | 9694 | 15.86 | 0.0010 | | | | |
| Error | 17 | 31 | | | 17 | 611 | | | | | | |

Table 7. Mean adult and juvenile *Spermophilus townsendii* densities on burned and shrubby sites and on sites inside and outside the OTA.

| | Mean Density (ha) | | Mean Density (ha) | |
|---|---|---|---|---|
| | Burned | Shrubby | Inside OTA | Outside OTA |
| Adults(n) | 14.4 (10) | 5.7 (10) | 16.2 (8) | 5.9 (12) |
| Juveniles (n) | 48.8 (10) | 19.1 (10) | 60.9 (8) | 15.9 (12) |

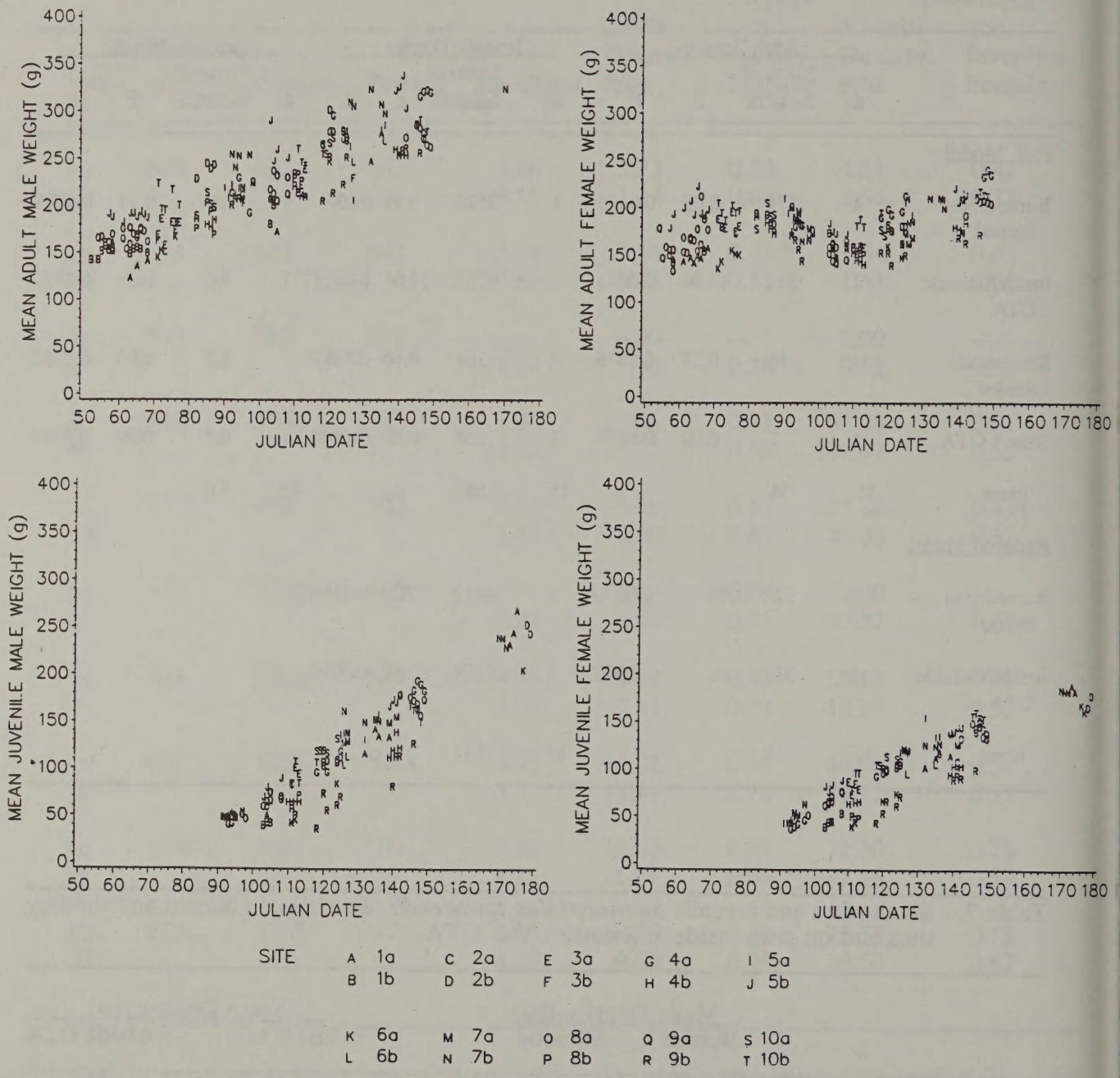


Fig. 2. Mean weights of adult and juvenile *Spermophilus townsendii* by sex for each site and date.

ratios were much more variable (Table 5). We found no relationship between degree of adult female skew and adult densities.

Male and female masses were similar at the start of the active season (Fig. 2). Average male mass increased at a fairly constant rate until immergence, while average female mass showed an initial increase, followed by a decrease associated with litter production, and a subsequent increase. Masses of adult females immerging remained about 100 g lower than masses of adult males immerging. Average masses of juvenile males showed a constant increase from birth to immergence, while average masses of females showed a similar initial rate of increase followed by a lower rate of increase, so that juvenile females entered the inactive period approximately 50 g lower in mass than juvenile males. Immergence of adults appeared to begin in the latter part of May, and was nearly complete by mid-June. Immergence of juveniles also began in May, but was not completed by the end of our trapping in late June.

"Survival" rates between cycle 1 and cycle 2 were between 45% and 84% on all sites for which there was sufficient data (Table 8). "Survival" rates between cycle 2 and 3 tended to be lower, ranging from 13 % to 59%. Among the sex and age classes, "survival" of juvenile males was particularly low (Table 8). There were no patterns in overall "survival" rates relative to site type.

## Vegetation and Diet by Site

Mean relative frequencies of vegetation and ground cover types tended to covary between paired sites (Table 9), with a few

Table 8. Proportion of *Spermophilus townsendii* captured during a trapping cycle that were known to be alive at the subsequent trapping cycle.

| Site | Cycle 1 - Cycle 2 | Cycle 2 - Cycle 3 |
|---|---|---|
| 1a | 0.67 | 0.22 |
| 1b | 0.80 | 0.18 |
| 2a | 0.60 | ----- |
| 2b | 0.50 | ----- |
| 3a | ----- | ----- |
| 3b | 0.50 | ----- |
| 4a | 0.79 | 0.13 |
| 4b | 0.45 | 0.39 |
| 5a | 0.65 | ----- |
| 5b | 0.79 | 0.29 |
| 6a | ----- | ----- |
| 6b | 0.80 | ----- |
| 7a | 0.53 | 0.34 |
| 7b | 0.67 | 0.29 |
| 8a | 0.81 | 0.39 |
| 8b | 0.78 | 0.59 |
| 9a | 0.50 | ----- |
| 9b | 0.84 | ----- |
| 10a | 0.46 | 0.43 |
| 10b | 0.73 | 0.39 |
| Sex/Age Class | | |
| Adult male | 0.67 | 0.29 |
| Adult female | 0.74 | 0.29 |
| Juvenile male | 0.12 | 0.17 |
| Juvenile female | 0.53 | 0.27 |

Table 9. Mean relative frequencies of vegetation and ground cover types on 20 sites used for trapping *Spermophilus townsendii* (see Table 1). Early season samples from 14 March - 9 April; late season samples from 17 April - 2 May.

| | SITE | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Early Season | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| Bare Ground | 55.8 | 55.7 | 16.2 | 32.3 | 56.9 | 47.8 | 56.1 | 44.9 | 36.1 | 34.5 | 35.6 | 42.8 | 26.3 | 43.6 | 58.1 | 37.0 | 38.9 | 30.4 | 32.0 | 32.9 |
| Litter | 20.3 | 21.4 | 20.5 | 17.3 | 25.7 | 27.1 | 18.3 | 28.9 | 12.1 | 23.5 | 49.1 | 29.9 | 39.7 | 34.5 | 18.9 | 34.9 | 17.2 | 25.3 | 29.3 | 31.9 |
| Rock | - | 0.1 | - | - | 0.2 | - | 0.1 | - | 0.5 | 3.7 | - | - | - | 1.5 | - | - | 2.9 | 1.5 | - | 0.3 |
| Cow Feces | 0.3 | - | 0.3 | 0.3 | - | - | 0.6 | 1.4 | - | - | 0.2 | - | 0.9 | 0.5 | 0.3 | - | - | - | 0.9 | 1.1 |
| Rabbit Feces | - | - | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | 0.4 | - | - | - |
| Sheep Feces | 0.3 | 0.3 | - | - | - | 0.3 | - | - | - | - | - | 0.3 | - | 0.2 | 0.5 | 0.5 | - | - | 0.1 | - |
| *Agropyron desertorum* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Allium* spp. | - | - | 0.1 | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | - | - | - | - |
| *Artemisia spinescens* | 4.5 | 1.2 | - | - | 0.4 | 0.4 | - | - | - | - | - | - | 0.7 | - | - | - | - | - | - | - |
| *Artemisia tridentata* | 1.0 | - | 34.7 | 21.3 | - | - | - | - | 33.3 | 17.2 | 0.1 | 0.3 | 0.3 | 0.1 | - | 0.1 | 22.1 | 18.9 | 0.9 | 0.1 |
| *Astragalus* spp. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Atriplex confertifolia* | - | - | - | - | 16.9 | 17.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Balsamorhiza hookeri* | - | - | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | 0.1 | - | - | - |
| *Bromus tectorum* | - | - | 21.9 | 4.7 | - | 0.3 | 0.1 | - | - | - | 15.3 | 0.1 | 8.7 | 0.3 | - | 2.6 | - | - | 0.8 | 1.1 |
| *Ceratoides lanata* (native) | 13.4 | 15.2 | - | - | - | 0.1 | - | - | - | - | - | 0.2 | - | - | 0.1 | - | - | - | - | - |
| *Ceratoides lanata* (exotic) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1.3 | 0.2 | - | - | - | - |
| *Delphinium bicolor* | - | - | - | 0.7 | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | - | - |
| *Elymus junceus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1.2 | - | - | - | - |
| *Grayia spinosa* | - | 0.9 | - | - | - | - | - | - | - | 0.7 | - | - | - | - | - | - | - | - | - | - |
| *Myosurus aristatus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.5 | 0.2 |
| *Oryzopsis hymenoides* | - | - | - | - | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | - |
| *Phlox aculeata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.1 | - |
| *Poa secunda* | 6.1 | 0.1 | 9.5 | 14.1 | 0.3 | 0.6 | 24.5 | 25.8 | 11.7 | 8.7 | 1.5 | 30.1 | 11.3 | 22.8 | 17.6 | 28.2 | 8.1 | 15.6 | 27.8 | 24.5 |
| *Ranunculus testiculatus* | - | - | - | - | - | - | - | - | 7.9 | 8.5 | 0.1 | - | 11.0 | 0.1 | 6.0 | - | 7.3 | 9.7 | 0.9 | 0.1 |
| *Salsola iberica* | - | - | - | - | - | - | 7.5 | 6.6 | - | 0.9 | 6.1 | 3.7 | 5.4 | 4.1 | 4.5 | 1.7 | - | - | 12.5 | 12.9 |
| *Sisymbrium altissimum* | - | - | - | - | - | - | - | 0.2 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sitanion hystrix* | - | - | 2.3 | 12.1 | 0.1 | 0.5 | 0.8 | 0.1 | 2.8 | 5.3 | - | - | 1.1 | 0.2 | 0.2 | 1.0 | 5.2 | 3.0 | 0.2 | 0.1 |
| *Tetradymia glabrata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

Table 9. Continued.

| | SITE | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| *Tortula ruralis* | 6.8 | 13.1 | 2.5 | 5.7 | 7.5 | 13.3 | - | 0.1 | 2.7 | 4.7 | - | - | 2.3 | - | 0.2 | 0.6 | 4.7 | 3.4 | 1.9 | 2.8 |
| Unknown | - | - | - | - | - | - | - | - | 1.0 | - | - | - | - | - | 0.3 | - | 1.1 | - | - | - |
| Unknown Forb | - | - | 0.1 | - | - | - | - | - | - | 0.1 | - | - | 0.3 | - | - | - | - | 0.1 | - | - |
| Unknown Mustard | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.1 | - |
| Late Season | | | | | | | | | | | | | | | | | | | | |
| Bare Ground | 46.8 | 43.3 | 13.9 | 22.6 | 49.2 | 48.4 | 48.7 | 48.7 | 41.3 | 41.4 | 50.0 | 50.8 | 36.4 | 36.1 | 58.1 | 40.5 | 37.9 | 24.7 | 50.8 | 38.5 |
| Litter | 20.6 | 28.9 | 15.1 | 20.1 | 24.5 | 31.9 | 25.5 | 25.6 | 16.7 | 16.4 | 37.4 | 23.5 | 33.7 | 35.9 | 18.9 | 26.2 | 13.8 | 25.7 | 30.7 | 27.1 |
| Rock | - | 0.1 | - | - | - | - | 0.1 | - | 0.5 | 3.1 | - | - | 0.3 | - | - | - | 1.3 | 0.7 | 0.1 | 0.5 |
| Cow Feces | 0.1 | - | 0.1 | 0.4 | - | - | 0.4 | 1.9 | 0.4 | - | 1.1 | 0.5 | 0.9 | 2.2 | 0.3 | - | 0.1 | - | 0.3 | 0.4 |
| Rabbit Feces | - | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | - | - | - | - |
| Sheep Feces | - | 0.3 | - | - | 0.2 | 0.4 | - | - | - | - | - | 0.5 | - | 0.1 | 0.5 | 0.3 | - | - | - | - |
| *Agropyron desertorum* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.7 | - | - |
| *Allium* spp. | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Artemisia spinescens* | 5.1 | 0.4 | - | - | 1.5 | 2.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Artemisia tridentata* | 0.2 | - | 42.1 | 25.7 | - | - | 0.1 | - | 25.7 | 19.4 | - | - | - | - | - | - | 31.3 | 22.9 | 0.3 | 0.6 |
| *Astragalus* spp. | - | - | - | - | - | - | - | - | - | - | - | - | 0.6 | - | - | - | - | - | - | - |
| *Atriplex confertifolia* | - | - | - | - | 16.1 | 19.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Balsamorhiza hookeri* | - | - | - | - | - | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - |
| *Bromus tectorum* | - | - | 11.7 | 3.3 | - | - | - | - | - | - | 15.0 | - | 9.8 | 1.5 | - | 2.8 | - | - | 0.1 | 1.9 |
| *Ceratoides lanata* (native) | 15.2 | 15.2 | - | - | - | 0.8 | - | - | - | - | - | 0.3 | - | 0.1 | 0.1 | 0.1 | - | - | - | - |
| *Ceratoides lanata* (exotic) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 1.3 | 0.3 | - | - | - | - |
| *Delphinium bicolor* | - | - | - | - | - | - | - | - | - | - | 0.2 | - | - | - | - | - | - | - | - | - |
| *Elymus junceus* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.9 | - | - | - | - |
| *Grayia spinosa* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Myosurus aristatus* | - | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | - | - | - | 0.1 |
| *Oryzopsis hymenoides* | - | - | - | - | - | 2.1 | - | - | - | - | - | 0.2 | - | - | - | 0.5 | - | - | - | - |
| *Phlox aculeata* | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Poa secunda* | 5.3 | - | 14.0 | 15.6 | 0.3 | 0.5 | 28.3 | 29.7 | 9.7 | 5.0 | 1.7 | 30.0 | 10.1 | 25.9 | 17.6 | 32.9 | 8.5 | 10.5 | 20.0 | 27.3 |
| *Ranunculus testiculatus* | - | - | - | 0.1 | - | - | - | - | 8.3 | 8.7 | - | - | 15.1 | 0.7 | 6.0 | - | 11.4 | 18.3 | 1.5 | 0.1 |
| *Salsola iberica* | - | - | - | - | - | - | 4.7 | 2.0 | 0.9 | 3.9 | 2.7 | 1.9 | 0.3 | 4.5 | 4.5 | 1.5 | - | 0.7 | 2.1 | 8.8 |
| *Sisymbrium altissimum* | - | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sitanion hystrix* | - | 0.2 | 6.7 | 16.6 | 0.8 | 1.9 | 0.1 | - | 3.7 | 3.4 | - | - | 0.1 | - | - | 1.5 | 1.3 | 3.0 | 1.9 | 1.0 |
| *Tetradymia glabrata* | - | 0.1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Tortula ruralis* | 14.7 | 19.5 | 4.3 | 3.6 | 15.3 | 0.3 | 0.1 | - | 0.7 | 6.7 | - | 0.3 | - | 0.8 | 0.2 | 0.6 | 2.4 | 1.5 | 0.1 | 1.5 |
| Unknown | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.3 | - | - | - | - | - |
| Unknown Forb | - | - | 0.1 | - | - | - | - | - | - | - | - | - | 0.7 | 0.1 | - | - | - | - | - | - |
| Unknown Mustard | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - |

shrub height and density to sagebrush site 2.

Juveniles late in the season consumed a wider variety of forage types than did adults early in the season, and included more arthropod parts in their diet (Table 11). *Poa* was a common food item, although it was replaced by *Ceratoides lanata* as a dominant food for juveniles on site pair 1, and for adults on site 1a. *Artemisia tridentata* was occasionally common in both adult and juvenile diets (site 9 for adults; sites 5 and 9 for juveniles). Juvenile diets (late season) showed more evidence of very young *Poa* shoots than did adult diets (early season).

**Hole Density vs Squirrel Density**

Because of continuing problems with unambiguous determination of active *S. townsendii* holes, despite coordination of methodology in the field with Steve Knick (Study 5) and Dana Quinney (IDARNG), we did not think the accuracy of our early hole counts warranted statistical analysis. We felt the count in June, following juvenile emergence, was most important in providing insight into productivity on our sites, and contained less bias than other counts because a single arbiter was used. Based on this count, there was a significant correlation between total estimated squirrel density in April or May (cycle 2) and June hole density within the trapping area on the "shrub" sites (site pairs 1, 2, 3, 5, and 9; $\underline{P} < 0.0001$, $\underline{R} = 0.98$; Spearman Rank; Fig. 3). The correlation was also positive on the remaining open sites, although not significant ($\underline{P} = 0.2004$, $\underline{R} = 0.44$). The number of holes per squirrel varied from 127 on site 6a where we caught just 1 squirrel for an estimated density of 0.3 squirrels/ha and counted 38.05 apparently active Townsend's ground squirrel holes/ha, to 62 on site 3a, to 22 or less on the remaining sites.

The random subset of holes that was followed on sites 4a and 1b after June showed a strong decline in the proportion considered active (Table 12). By 5 August less than half the holes designated as "active" in our study were considered "active" by the Study 5 criteria on the winterfat site. It is likely that the rate of change from "active" to "inactive" is dependent on wind and rain patterns in combination with observer bias.

DISCUSSION

During the 1991 season it appeared that productivity of *S. townsendii* was high overall in comparison with earlier studies (Smith and Johnson 1985). Availability of *Poa secunda* was high on the burned sites, and this species was the food most frequently identified during observations of foraging animals (Sharpe et al. this volume); this may, in part, explain the high densities of adults and juveniles on the burned sites. Because of uncertainties in the estimation of juvenile densities during the period of juvenile emergence, when the population is clearly not closed, and because of trap saturation by juveniles, we think estimated juvenile density is a better measure of productivity than the number of juveniles per female.

We do not fully understand the later production of offspring on some sites as the pattern is inconsistent with location, adult weights, and habitat type. Plant phenology may play an important role. We do not know why densities are higher on tracked sites, although we did observe that animals seem to prefer to burrow into the side of depressions caused by tracked vehicles. We do not know why sex ratios are skewed toward females.

Lower "survival" rates between cycle 2 and cycle 3 are probably a result of some combination of immergence into burrows, and increased dispersal movements. Low "survival" rates of juvenile males are consistent with higher rates of dispersal for juvenile males as compared to juvenile

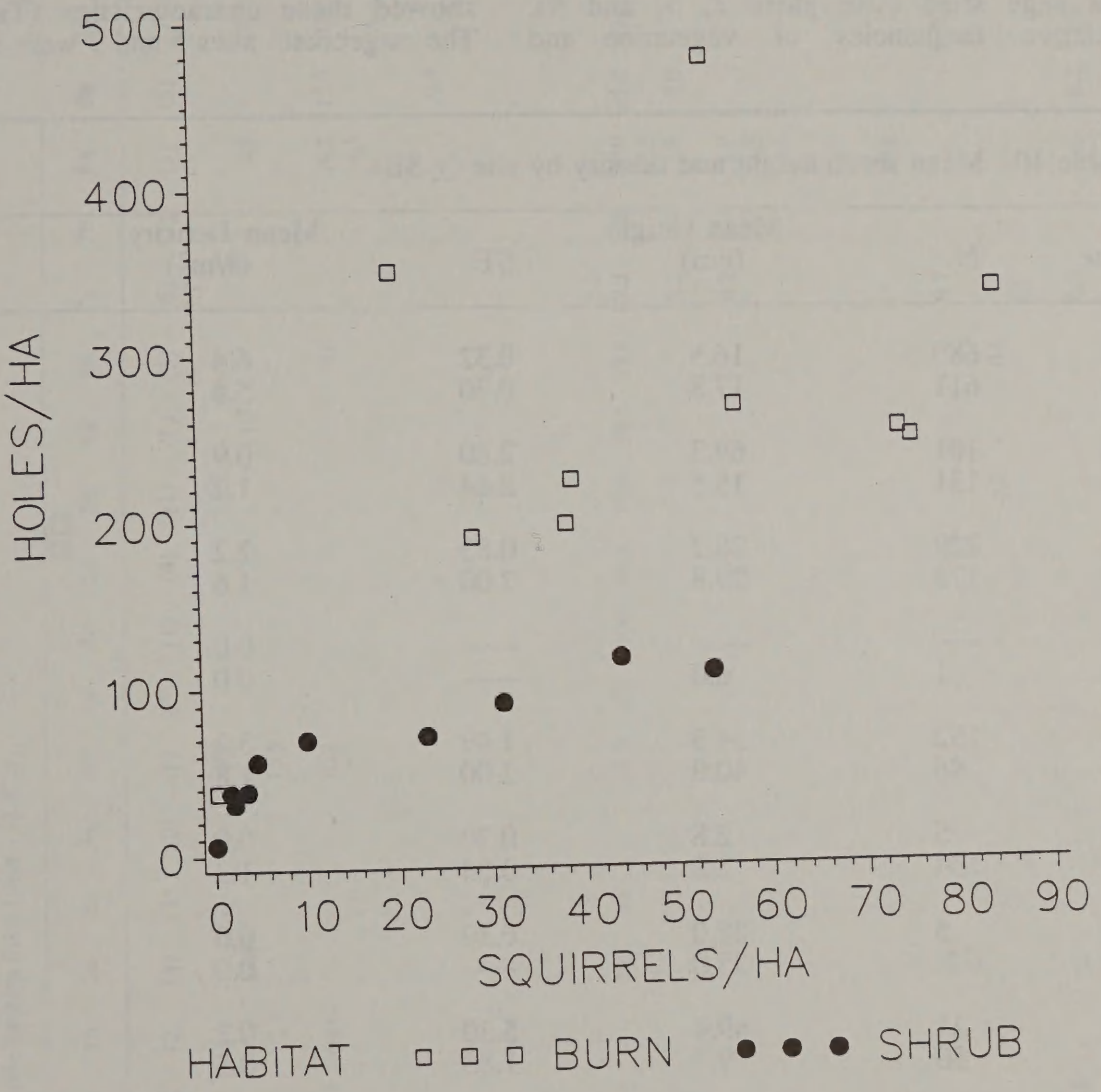


Fig. 3. Comparison of hole densities in early June inside the trapping areas on each site with total densities of *Spermophilus townsendii* in late April/May.

exceptions. Bare ground was more common on site 2b than on site 2a, and on site 7b than on site 7a. *Poa secunda* was found on most plots, although its relative frequency varied from 0.1 (site 3a, shadscale outside the OTA) to 28.2 (site 8b, burned and seeded winterfat outside the OTA). *Artemisia tridentata* was most common on the sage sites (site pairs 2, 5, and 9). Relative frequencies of vegetation and ground cover types did not change much between the early and late season samples.

Protection from raptors by vegetation is probably provided by a combination of tall and dense shrubs. Site pairs 2 (sagebrush outside the OTA), 3 (shadscale outside the OTA), 5 and 9 (sagebrush inside the OTA) showed these characteristics (Table 10). The sagebrush sites 5 and 9 were similar in

Table 10. Mean shrub height and density by site (± SE).

| Site | N | Mean Height (cm) | SE | Mean Density (#/m²) | SE |
|---|---|---|---|---|---|
| 1a | 680 | 16.5 | 0.32 | 6.4 | 0.39 |
| 1b | 611 | 17.8 | 0.30 | 5.8 | 0.36 |
| 2a | 101 | 69.3 | 2.80 | 0.9 | 0.19 |
| 2b | 131 | 15.5 | 2.64 | 1.2 | 0.19 |
| 3a | 229 | 28.7 | 0.83 | 2.2 | 0.28 |
| 3b | 173 | 29.8 | 2.00 | 1.6 | 0.25 |
| 4a | ---- | ----- | ----- | 0.0 | ----- |
| 4b | 1 | 6.0 | ----- | 0.0 | ----- |
| 5a | 152 | 34.3 | 1.49 | 3.2 | 0.41 |
| 5b | 86 | 40.9 | 2.00 | 1.8 | 0.28 |
| 6a | 5 | 2.8 | 0.20 | 0.0 | 0.02 |
| 6b | 134 | 3.2 | 0.34 | 1.3 | 0.27 |
| 7a | 5 | 28.0 | 6.39 | 0.0 | 0.03 |
| 7b | 1 | 35.0 | ----- | 0.0 | 0.01 |
| 8a | 21 | 49.4 | 5.30 | 0.2 | 0.05 |
| 8b | 50 | 9.1 | 1.83 | 0.5 | 0.13 |
| 9a | 133 | 34.3 | 1.66 | 1.2 | 0.29 |
| 9b | 103 | 41.5 | 2.09 | 2.2 | 0.33 |
| 10a | 57 | 13.2 | 1.72 | 0.5 | 0.11 |
| 10b | 46 | 15.2 | 1.80 | 0.4 | 0.14 |

Table 11. Number of animals sampled and mean relative frequencies of food types in adult and juvenile male and female *Spermophilus townsendii* feces by site. Adult samples from 23 Feb - 14 Apr and juvenile samples from 1 Apr - 21 May.

| | SITE | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| Adult Males | | | | | | | | | | | | | | | | | | | | |
| Number sampled | (3) | (2) | (3) | (1) | (0) | (1) | (3) | (1) | (4) | (1) | (1) | (3) | (6) | (5) | (5) | (5) | (7) | (5) | (3) | (4) |
| *Agropyron* | - | - | - | - | | - | - | - | - | - | - | - | 0.5 | - | - | - | - | - | - | - |
| *Artemisia frigida* | - | - | - | - | | 9.7 | - | - | - | 2.5 | - | - | - | - | - | - | - | - | - | - |
| *Artemisia tridentata* | - | - | 27.8 | - | | - | - | - | 3.5 | - | 1.7 | - | - | - | 2.9 | - | 28.1 | 19.3 | 0.6 | - |
| *Atriplex* | - | 2.6 | - | - | | 15.5 | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Bromus* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Ceratoides lanata* | 29.1 | 96.6 | - | - | | 70.1 | - | - | - | - | - | 0.6 | - | - | 19.2 | 15.7 | 0.2 | - | - | - |
| *Chrysothamnus* | - | - | - | - | | - | - | - | - | - | - | - | - | - | 4.3 | - | - | - | - | - |
| *Crepis* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | 0.4 | - | - | - |
| *Cryptantha* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Descurainia* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | 0.4 | - | - | - | - |
| *Draba* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Kochia* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Lactuca* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Lepidium* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Medicago-Melilotus* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Phlox* | - | - | - | - | | - | - | - | - | - | - | - | 5.0 | - | - | - | - | - | - | - |
| *Poa* | 70.1 | - | 70.9 | 100 | | 4.6 | 100 | 100 | 96.5 | 92.4 | 98.3 | 98.9 | 89.3 | 100 | 60.9 | 81.0 | 70.0 | 80.6 | 98.9 | 97.7 |
| *Poa* (young) | - | - | - | - | | - | - | - | - | - | - | - | - | - | 2.5 | - | - | - | - | - |
| *Salsola iberica* | - | - | - | - | | - | - | - | - | - | - | - | 2.2 | - | 1.9 | 2.0 | - | - | 0.6 | 1.3 |
| *Sarcobatus vermiculatus* | - | 0.8 | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Sisymbrium altissimum* | - | - | - | - | | - | - | - | - | - | - | - | 0.7 | - | 1.7 | - | - | - | - | - |
| *Sitanion* | - | - | - | - | | - | - | - | - | - | - | - | - | - | 2.5 | - | - | - | - | - |
| *Stipa-Oryzopsis* | - | - | - | - | | - | - | - | - | - | - | - | - | - | 1.6 | - | - | - | - | - |
| *Tetradymia* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| *Vulpia* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | 0.4 | - | - | - |
| *Endogone*-fungus | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Grass Seed and Glume | - | - | - | - | | - | - | - | - | - | - | - | - | - | 0.8 | - | - | - | - | - |
| Lichen | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Moss | - | - | - | - | | - | - | - | - | - | - | - | 0.7 | - | - | - | 0.4 | - | - | - |
| Seed | - | - | 0.6 | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.6 |
| Unknown Bark | - | - | - | - | | - | - | - | - | 5.1 | - | 0.6 | - | - | - | - | - | - | - | 0.4 |
| Unknown Forb | - | - | - | - | | - | - | - | - | - | - | - | 0.7 | - | - | - | - | - | - | - |
| Unknown Forb I | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Arthropod | 0.8 | - | 0.7 | - | | - | - | - | - | - | - | - | 0.7 | - | 1.6 | 0.4 | 0.4 | - | - | - |

Table 11. Continued.

| | SITE | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| Coleoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | 0.5 | - | - | - | - |
| Lepidoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Orthoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Coleoptera-Lepidoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Coleoptera-Orthoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Adult Females | | | | | | | | | | | | | | | | | | | | |
| Number sampled | (3) | (3) | (2) | (1) | (1) | (3) | (7) | (2) | (6) | (3) | (0) | (7) | (26) | (4) | (13) | (12) | (12) | (7) | (3) | (7) |
| *Agropyron* | - | - | - | - | - | - | - | - | - | - | | - | 0.1 | - | - | - | - | - | - | - |
| *Artemesia frigida* | - | - | - | - | 8.9 | 22.4 | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Artemesia tridentata* | 0.7 | - | 0.8 | - | 13.7 | - | - | - | 2.3 | 32.5 | | - | - | - | 0.6 | - | 44.5 | 5.2 | - | - |
| *Atriplex* | - | 0.5 | - | - | 13.7 | 9.1 | - | - | - | 0.6 | | - | - | - | - | 0.3 | - | - | - | - |
| *Bromus* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Ceratoides lanata* | 7.5 | 96.1 | - | - | - | 58.3 | - | - | - | - | | - | 0.2 | - | 10.2 | 1.1 | - | - | - | - |
| *Chrysothamnus* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Crepis* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Cryptantha* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Descurainia* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Draba* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.2 | - | - | - |
| *Kochia* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Lactuca* | - | - | - | - | - | - | - | - | - | - | | - | 0.4 | - | - | - | - | - | - | - |
| *Lepidium* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Medicago-Melilotus* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Phlox* | - | - | - | - | - | - | - | - | - | 3.7 | | - | 2.7 | - | - | - | - | - | - | - |
| *Poa* | 91.8 | 1.4 | 99.2 | 100. | 45.1 | 6.3 | 100 | 100 | 97.0 | 62.1 | | 99.8 | 93.2 | 98.7 | 88.5 | 94.6 | 52.6 | 94.7 | 99.4 | 98.9 |
| *Poa* (young) | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Salsola iberica* | - | - | - | - | - | - | - | - | - | - | | 0.2 | 2.7 | 0.8 | 0.1 | 1.9 | - | - | - | 0.8 |
| *Sarcobatus vermiculatus* | - | 1.2 | - | - | - | 2.9 | - | - | - | 1.2 | | - | - | - | - | - | - | - | - | - |
| *Sisymbrium altissimum* | - | - | - | - | - | - | - | - | - | - | | - | 0.2 | - | - | 0.4 | - | - | - | - |
| *Sitanion* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Stipa-Oryzopsis* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Tetradymia* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Vulpia* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | 0.3 | - | - | - | - |
| *Endogone*-fungus | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Grass Seed and Glume | - | - | - | - | 18.8 | - | - | - | - | - | | - | 0.3 | - | - | 0.2 | - | - | - | - |
| Lichen | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Moss | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.2 | - | - | - |
| Seed | - | - | - | - | - | - | - | - | 0.7 | - | | - | - | - | - | - | - | - | - | - |

Table 11. Continued

| | SITE | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| Unknown Bark | - | - | - | - | - | - | - | - | - | - | | - | 0.1 | 0.4 | - | 0.3 | 2.5 | - | 0.6 | - |
| Unknown Forb | - | - | - | - | - | - | - | - | - | - | | - | 0.1 | - | - | - | - | - | - | - |
| Unknown Forb I | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Arthropod | - | - | - | - | - | - | - | - | - | - | | - | - | - | 0.6 | 0.5 | - | - | - | 0.3 |
| Coleoptera | - | 0.7 | - | - | - | 0.9 | - | - | - | - | | - | - | - | - | 0.3 | - | - | - | - |
| Lepidoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Orthoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Coleoptera-Lepidoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Coleoptera-Orthoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Juvenile Males | | | | | | | | | | | | | | | | | | | | |
| Number sampled | (4) | (3) | (5) | (2) | (0) | (6) | (7) | (7) | (5) | (5) | (0) | (7) | (23) | (4) | (7) | (11) | (12) | (7) | (7) | (6) |
| *Agropyron* | - | - | - | 9.1 | | 3.4 | 0.9 | 0.4 | - | 0.5 | 0.9 | - | - | 0.6 | 2.3 | 2.1 | - | 0.2 | - | |
| *Artemisia frigida* | - | - | - | - | | 7.5 | - | - | - | - | - | - | - | - | - | 0.8 | - | - | - | |
| *Artemisia tridentata* | - | - | 45.8 | 3.3 | | 0.5 | - | - | 58.9 | 63.6 | - | - | - | 1.8 | - | 33.7 | 37.1 | 3.9 | - | |
| *Atriplex* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| *Bromus* | - | - | 1.1 | 5.1 | | - | - | 0.3 | 0.5 | - | - | - | 0.8 | - | 0.3 | 0.8 | - | - | - | |
| *Ceratoides lanata* | 82.8 | 97.8 | 0.6 | 29.1 | | 82.3 | 2.9 | - | - | - | - | - | - | 24.3 | 12.0 | - | - | - | - | |
| *Chrysothamnus* | - | - | - | - | | - | - | - | - | 0.8 | - | 0.4 | - | 3.5 | - | 0.8 | 1.8 | 1.3 | - | |
| *Crepis* | 0.5 | - | 0.6 | 3.3 | | - | - | - | - | - | - | - | - | - | - | 0.9 | - | - | 0.5 | |
| *Cryptantha* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| *Descurainia* | - | - | 0.7 | 3.5 | | - | - | - | - | - | - | - | - | 0.6 | - | - | 1.0 | - | - | |
| *Draba* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | 0.7 | - | - | - | |
| *Kochia* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| *Lactuca* | - | - | - | - | | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | |
| *Lepidium* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| *Medicago-Melilotus* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| *Phlox* | - | - | - | - | | - | - | - | 1.6 | - | - | 0.2 | - | - | - | - | - | 2.1 | - | |
| *Poa* | 6.7 | - | 35.3 | 41.4 | | 4.0 | 93.0 | 97.7 | 34.5 | 34.4 | 89.1 | 95.9 | 89.0 | 53.7 | 75.7 | 52.7 | 51.9 | 88.7 | 92.2 | |
| *Poa* (young) | - | - | 12.0 | - | | - | - | - | - | - | - | - | - | - | - | 1.0 | - | - | - | |
| *Salsola iberica* | - | - | - | - | | - | 0.2 | 0.4 | - | - | 1.1 | 2.3 | 1.3 | 1.1 | 1.3 | - | 0.7 | 3.2 | 2.4 | |
| *Sarcobatus vermiculatus* | 0.5 | 0.5 | - | - | | - | - | - | - | 0.3 | - | - | - | - | - | - | - | - | - | |
| *Sisymbrium altissimum* | 1.0 | - | - | - | | - | - | - | - | - | - | - | 0.5 | 0.6 | - | - | 0.3 | - | - | |
| *Sitanion* | - | - | - | - | | 0.3 | - | - | - | - | - | - | 1.4 | 7.1 | 3.3 | 0.6 | - | - | - | |
| *Stipa-Oryzopsis* | 1.5 | - | - | - | | - | - | - | 3.0 | - | - | - | - | 1.1 | - | 1.0 | 6.2 | 0.5 | - | |
| *Tetradymia* | - | - | - | - | | - | - | - | - | - | - | 0.1 | - | - | - | - | - | - | - | |

Table 11. Continued.

| | SITE | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| *Vulpia* | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| *Endogone*-fungus | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | 0.4 | - | - | - | |
| Grass Seed and Glume | 1.0 | - | - | - | | 0.4 | 2.1 | - | 0.5 | - | 0.4 | 0.4 | 0.6 | 0.6 | 3.6 | - | 0.4 | - | - | |
| Lichen | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Moss | 0.5 | 0.5 | 1.4 | - | | - | - | - | - | - | 1.8 | - | - | 1.1 | - | 0.6 | - | - | - | |
| Seed | - | - | - | - | | - | - | - | - | - | - | 0.1 | - | - | - | 1.3 | - | - | - | |
| Unknown Bark | - | - | - | - | | - | - | 1.1 | - | 0.4 | 0.5 | 0.2 | - | - | - | 2.2 | - | - | 0.3 | |
| Unknown Forb | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | 0.3 | - | - | - | |
| Unknown Forb I | - | - | - | - | | - | 0.4 | - | - | - | - | - | - | - | - | - | - | - | - | |
| Arthropod | 5.5 | - | 2.5 | - | | - | 0.3 | 0.3 | 0.8 | - | 4.6 | 0.4 | 1.9 | 1.7 | 0.3 | 0.2 | 0.5 | - | 1.0 | |
| Coleoptera | - | 1.1 | 5.2 | - | | 1.4 | - | - | - | - | 1.6 | - | 4.4 | 1.7 | - | - | - | - | 3.5 | |
| Lepidoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Orthoptera | - | - | - | - | | - | - | - | - | - | - | - | - | 0.6 | - | - | - | - | - | |
| Coleoptera-Lepidoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | 1.2 | - | - | - | - | |
| Coleoptera-Orthoptera | - | - | - | - | | - | - | - | - | - | - | - | - | - | - | - | - | - | - | |
| Juvenile Females | | | | | | | | | | | | | | | | | | | | |
| Number sampled | 7 | 5 | 4 | 5 | 1 | 8 | 7 | 7 | 5 | 8 | 0 | 13 | 19 | 5 | 5 | 8 | 17 | 7 | 6 | 7 |
| *Agropyron* | 0.3 | - | - | 27.1 | - | 6.9 | - | 0.4 | - | 0.6 | | 0.2 | 0.2 | - | - | 1.4 | 1.7 | 2.5 | - | - |
| *Artemesia frigida* | 0.4 | - | - | 0.8 | 8.9 | 17.2 | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Artemesia tridentata* | 0.9 | - | 45.8 | 24.3 | 13.7 | - | - | - | 55.5 | 55.9 | | - | - | - | 2.9 | - | 25.2 | 48.8 | 31.7 | - |
| *Atriplex* | - | - | - | 0.6 | 13.7 | 0.9 | - | - | - | - | | - | 0.2 | - | - | - | - | - | - | - |
| *Bromus* | - | - | 1.1 | 4.1 | - | 0.6 | 1.1 | 0.3 | - | - | | - | - | 0.5 | - | - | 0.5 | - | - | - |
| *Ceratoides lanata* | 84.8 | 96.9 | 0.6 | 19.1 | - | 58.0 | - | 3.2 | - | 0.4 | | 0.4 | - | - | 22.0 | 3.0 | - | - | - | - |
| *Chrysothamnus* | - | - | - | - | - | - | - | 2.5 | - | 0.8 | | - | 0.2 | - | 23.7 | - | 0.6 | 0.9 | 2.4 | 0.8 |
| *Crepis* | 0.7 | - | 0.6 | - | - | - | - | - | - | - | | - | - | - | - | - | 1.1 | - | - | - |
| *Cryptantha* | 0.6 | - | - | - | - | 0.3 | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Descurainia* | - | - | 0.7 | 5.7 | - | 0.4 | - | - | - | - | | - | 0.3 | 0.5 | 0.7 | - | 2.8 | 0.4 | - | - |
| *Draba* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.7 | - | - | - |
| *Kochia* | - | - | - | - | - | - | - | - | - | - | | 2.0 | - | - | - | - | - | - | - | - |
| *Lactuca* | - | - | - | - | - | - | - | - | - | - | | - | 0.2 | - | - | - | 0.4 | - | - | - |
| *Lepidium* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.6 | - | - | - |
| *Medicago-Melilotus* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.2 | - | - | - |
| *Phlox* | - | - | - | - | - | - | - | - | 0.5 | 0.9 | | - | 0.2 | - | - | - | - | - | 1.2 | - |
| *Poa* | 5.1 | - | 35.3 | 4.7 | 45.1 | 3.8 | 94.6 | 91.6 | 42.1 | 40.8 | | 93.3 | 89.7 | 91.6 | 39.0 | 87.7 | 66.8 | 45.0 | 57.0 | 92.6 |
| *Poa* (young) | - | - | 12.0 | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Salsola iberica* | - | 0.3 | - | - | - | - | - | 1.2 | - | - | | 0.6 | 1.8 | 2.2 | 4.2 | 2.3 | - | 0.4 | 6.4 | - |
| *Sarcobatus vermiculatus* | 0.2 | - | - | - | - | 0.5 | - | - | - | 0.3 | | - | - | - | - | 0.5 | - | - | - | 1.0 |

Table 11. Continued.

| | SITE | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1a | 1b | 2a | 2b | 3a | 3b | 4a | 4b | 5a | 5b | 6a | 6b | 7a | 7b | 8a | 8b | 9a | 9b | 10a | 10b |
| *Sisymbrium altissimum* | 1.4 | - | - | 0.8 | - | - | - | - | - | - | | - | - | 0.5 | 0.9 | - | - | - | - | - |
| *Sitanion* | - | - | - | 13.1 | - | - | 0.5 | 0.3 | - | - | | - | 1.1 | 1.2 | 1.6 | 0.5 | 1.0 | 0.7 | - | - |
| *Stipa-Oryzopsis* | 0.2 | - | - | - | - | - | - | - | 1.0 | - | | - | - | - | - | - | 0.6 | 0.4 | - | - |
| *Tetradymia* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.1 | - | - | - |
| *Vulpia* | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| *Endogone*-fungus | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | 0.5 | - | - | - |
| Grass Seed and Glume | 0.2 | - | - | - | 18.8 | 1.1 | 2.1 | - | - | - | | 1.0 | 1.4 | - | - | 0.9 | 0.2 | - | 0.6 | - |
| Lichen | - | - | - | - | - | 0.5 | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Moss | 1.2 | 1.0 | 1.4 | - | - | - | - | - | 0.4 | 0.3 | | 0.2 | - | - | - | 1.1 | 0.8 | - | - | 0.6 |
| Seed | - | - | - | - | - | - | - | - | - | - | | - | 0.1 | - | - | - | 0.1 | 0.5 | - | - |
| Unknown Bark | - | - | - | - | - | 0.4 | - | 0.4 | - | - | | - | 2.5 | - | - | 1.5 | 1.3 | 0.4 | - | - |
| Unknown Forb | - | - | - | - | - | - | 0.3 | - | - | - | | - | 0.2 | - | - | - | - | - | - | - |
| Unknown Forb I | - | - | - | - | - | - | 0.3 | - | - | - | | - | - | - | - | - | - | - | - | - |
| Arthropod | 3.9 | - | 2.5 | - | - | - | 1.1 | - | 0.5 | - | | 1.5 | 1.9 | 3.5 | - | - | 0.1 | - | 0.6 | 4.0 |
| Coleoptera | - | 1.7 | - | - | - | 3.7 | - | - | - | - | | 0.7 | - | - | 4.8 | 0.5 | 0.2 | - | - | 0.9 |
| Lepidoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | 0.8 | - | - | - | - |
| Orthoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Coleoptera-Lepidoptera | - | - | - | - | - | - | - | - | - | - | | - | - | - | - | - | - | - | - | - |
| Coleoptera-Orthoptera | - | - | - | - | - | 5.5 | - | - | - | - | | - | - | - | - | - | - | - | - | - |

females, as Sherman (1981) has reported for Belding's ground squirrel (*Spermophilus beldingi*).

We have not yet had an opportunity to analyze the vegetation and diet data, but it does appear that the squirrels are being very selective in their diets. Visual inspection of the means suggests that on sites where *Ceratoides lanata* comprises a relatively high proportion of the diet, rates of gain in mass may be lower; we will test this possibility.

The hole counts in our studies appear to be somewhat useful indicators of relative densities within burned or shrubby types, although it seems evident that we are including holes used by other species in our tally of active holes. Use of holes by other species (*D. ordii*, *D. microps*, and *Tamias minimus*) in combination with identification of inactive holes as being active may be responsible for the sometimes large and inconsistent number of estimated active holes per squirrel. It seems clear that holes disappear rapidly and in an inconsistent fashion following immergence by squirrels (Table 12). Differences in criteria used to identify active and inactive holes by studies 4 and 5, resulting in part from differences in the time at which holes are counted, may cause inconsistencies between the studies in the counts of active holes. We recommend that hole counts for all studies be completed by the end of June.

Table 12. Activity classification of 40 holes randomly selected from holes considered to be actively used by *Spermophilus townsendii* in early June, 1991.

| Site | Date | Proportion active |
|---|---|---|
| 4a | 13 Jun 91 [a] | 1.00 |
| | 28 Jun 91 [b] | 0.80 |
| | 05 Aug 91 [c] | 0.00 |
| | 05 Aug 91 [d] | 0.75 |
| 1b | 05 Jun 91 [a] | 1.00 |
| | 26 Jun 91 [b] | 0.55 |
| | 05 Aug 91 [c] | 0.05 |
| | 05 Aug 91 [d] | 0.45 |

[a] Sampled by Study 4.
[b] Sampled by Bob Schooley with Study 4 criteria.
[c] Sampled by Libby Kvaalen with Study 4 criteria.
[d] Sampled by Libby Kvaalen with Study 5 criteria.

## PLANS FOR NEXT SEASON

To get better estimates of dates of emergence and immergence by sex and age class we will trap for just 1 day on a site before moving to the next site. Population density estimates will be based on data over a 3- or more- week period. To improve our estimates of adult densities we will expand the trapping areas on some sites. On high density sites, we will trap a smaller area following juvenile emergence to get good estimates of juvenile densities.

Because of irregular appearance and disappearance of holes, in combination with a varying population demography associated with staggered emergence dates and timing of reproduction, we do not feel information gained from hole enumeration prior to June has sufficient value to warrant the tremendous effort required. Thus we plan to restrict our hole counting to early June, when juveniles have emerged and adults are immerging, and we do not plan to map burrow entrances.

We will sample plant phenology on the sites to get information on among-site differences. Vegetation will be measured on each site 3 times during the season, and fecal material will be collected for diet analysis in synchrony with the vegetation sampling.

Because of the large distances moved by the squirrels we will use a grid-based scheme for placing traps, shifting the grid in a regular fashion to get even coverage of the study sites.

## ACKNOWLEDGMENTS

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# Preliminary Report on the Behavior of *Spermophilus townsendii* in Different Habitat Types

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*Annual Summary*

*Adult male and female individuals of Townsend's ground squirrel (Spermophilus townsendii) were observed in different habitats from February through May. Based on the sampling of observation strings, each encompassing a single trip out of a hole and back into a hole, females spend more time engaging in behaviors associated with vigilance than do males. Ground squirrels on burned areas spend a greater proportion of their above-ground time consuming grass than do ground squirrels in shrubby areas.*

## OBJECTIVES

1. To determine whether behaviors of the Townsend's Ground Squirrel, (*Spermophilus townsendii*) differ among sexes and habitat types.

2. To understand the factors that influence foraging behavior.

## METHODS

Data on *S. townsendii* were collected from 20 February through 16 May 1991 by E.C. Atkinson. Prior to data collection, Atkinson observed ground squirrels to identify various behavior patterns and designate codes for each behavior. Observations were made on squirrels that had been marked with hair dye to indicate sex and age (Van Horne et al., this volume). Atkinson observed ground squirrels on 7 separate sites (Sites 1a, 4a, 7a, 10a, 2b, 5b, 7b; see Van Horne et al., this volume, Table 1) from a step ladder using binoculars. Observations of behavior, distance to cover, distance to the burrow from which the squirrel emerged, and distance moved were recorded at 20-sec intervals on a Polycorder electronic notebook (Omnidata International, Inc., Logan, UT). Mean proportion of time spent in each activity and at each distance were summarized for each observation string. These means were analyzed using single-factor ANOVA tests that compared values among site types, months, or sexes. A Bonferroni adjustment was made for the original alpha of 0.05, by dividing alpha by the number of comparisons (pooled categories of overall foraging and activity not included), resulting in an alpha of 0.003 (0.05/15). In future analyses we will reduce

the number of activities tested and will use a single model for each activity with multiple effects.

In most cases observation strings consisted of the period of time beginning with the emergence of a squirrel from a hole and ending when the animal stayed in a burrow for at least 1 min. The proportion of time spent in each activity was calculated for each string of observations and arcsine-transformed prior to analysis. Only observations in which the animal was visible were included in calculating the proportions. Data from all observed animals were used when comparing habitat types and months, but only observations of known sex animals were used when testing for sex differences. Because animals were not individually marked, the number of animals sampled may be smaller than the number of observation strings which we have used to determine n in our comparisons.

## RESULTS

Only activities that comprised > 1% of the mean of observation strings across all animals were analyzed, and these included 12 identified activities, plus 2 grouped categories (overall activity and overall foraging). "Ingesting grass" and/or "vigilance" accounted for the highest proportion of observed activities by sex, habitat type, and month (Tables 1-3). Inspection of foraging sites following behavioral observations indicated that nearly all the grass ingested was either new growth of *Poa secunda*, or the lighter-colored tissue near the base of older stems. In the latter instance, a ring consisting of the blade ends would be left on the ground around a grass clump. Due to our conservative alpha level (Bonferroni adjusted alpha) of 0.003, there were few significant differences found, although there were some interesting trends.

Overall, males spent a greater proportion of their above-ground time foraging (especially on grasses) and sitting than females, although these differences were not significant. Females spent more time being vigilant, although this was also not significant at the Bonferroni adjusted alpha level (Table 1).

When activity was compared by habitat type, ground squirrels in burned habitats were observed foraging significantly more than those in shrubby habitats, especially on grasses. Although not significant, they also spent a greater proportion of their time visiting burrows than did those in shrubby habitats. The squirrels in shrubby habitats were more vigilant and were observed walking and sitting more often, although these were also not significant (Table 2).

There were no significant differences when the activities were compared by month. Proportion of above-ground time ingesting both grasses and forbs generally increased from February through May, as did basking, handling food, and overall foraging. The proportion of time spent sitting, walking, and running was highest during February and then generally decreased through May (Table 3).

## DISCUSSION

The high rate of grass ingestion observed supports the findings of Smith and Johnson (1985), who reported that grasses comprised 60% of the food ingested by Townsend's ground squirrels in the Snake River Birds of Prey Area (SRBOPA). Yensen (1989) also reported that grasses often comprised over 50% of the diet (37-88% relative density) of *S. townsendii*

Table 1. Comparison of Townsend's ground squirrel (*Spermophilus townsendii*) behavior (composing ≥ 1% of all observed behavior) and movements by sex.

| Activity | Male | | | Female | | | Prob. > F [a] |
|---|---|---|---|---|---|---|---|
| | n | Mean | SE | n | Mean | SE | |
| Ingest Grass | 21 | 37.9 | 6.6 | 45 | 24.7 | 3.7 | 0.0734 |
| Vigilance | 21 | 13.6 | 4.0 | 45 | 27.8 | 4.2 | 0.0458 |
| Sit | 21 | 13.4 | 4.6 | 45 | 3.8 | 0.8 | 0.0144 |
| Bask | 21 | 4.8 | 2.7 | 45 | 9.1 | 3.3 | 0.4083 |
| Ingest Forbs | 21 | 4.5 | 2.1 | 45 | 5.9 | 1.7 | 0.6241 |
| Walk | 21 | 7.5 | 2.0 | 45 | 4.6 | 1.0 | 0.1339 |
| In Burrow | 21 | 8.0 | 2.2 | 45 | 10.6 | 1.8 | 0.2890 |
| Handle Food | 21 | 1.7 | 1.1 | 45 | 1.1 | 0.5 | 0.5296 |
| Run | 21 | 3.0 | 1.1 | 45 | 2.6 | 0.9 | 0.4946 |
| Dig for Food | 21 | 0.5 | 0.2 | 45 | 2.4 | 1.0 | 0.3426 |
| Get Nest Material | 21 | 2.2 | 2.2 | 45 | 1.1 | 1.0 | 0.6908 |
| Groom | 21 | 0.1 | 0.1 | 45 | 2.5 | 1.6 | 0.2041 |
| Active (while above ground) | 21 | 81.8 | 4.8 | 45 | 87.1 | 3.5 | 0.3009 |
| Forage (overall) | 21 | 44.6 | 6.4 | 45 | 34.3 | 4.3 | 0.1603 |
| Movements (m) | | | | | | | |
| Distance from Cover | 21 | 1.8 | 0.3 | 45 | 3.0 | 0.5 | 0.1659 |
| Distance to Burrow | 21 | 1.5 | 0.2 | 45 | 3.3 | 0.8 | 0.2335 |
| Distance Moved | 21 | 0.6 | 0.3 | 45 | 1.7 | 0.7 | 0.2785 |

[a] Analysis run on arcsine-transformed values of all proportions.

Table 2. Comparison of Townsend's ground squirrel (*Spermophilus townsendii*) behaviors (composing ≥ 1% of all observed behavior) and movements by site type (burned or shrubby).

| Activity | Burned Habitat n | Mean | SE | Shrubby Habitat n | Mean | SE | Prob. > F [a] |
|---|---|---|---|---|---|---|---|
| Ingest Grass | 64 | 31.1 | 3.3 | 12 | 6.3 | 4.6 | 0.0006 |
| Vigilance | 64 | 22.0 | 3.2 | 12 | 47.7 | 9.5 | 0.0047 |
| Sit | 64 | 6.3 | 1.3 | 12 | 16.4 | 6.9 | 0.0260 |
| Bask | 64 | 7.5 | 2.5 | 12 | 2.5 | 1.7 | 0.4410 |
| Ingest Forbs | 64 | 5.2 | 1.4 | 12 | 2.2 | 1.5 | 0.4372 |
| Walk | 64 | 5.1 | 0.9 | 12 | 9.9 | 3.0 | 0.0414 |
| In Burrow | 64 | 10.3 | 1.5 | 12 | 4.1 | 2.2 | 0.0094 |
| Handle Food | 64 | 1.2 | 0.5 | 12 | 0.3 | 0.3 | 0.4735 |
| Run | 64 | 2.8 | 0.7 | 12 | 4.1 | 1.5 | 0.2276 |
| Dig for Food | 64 | 1.6 | 0.6 | 12 | 2.2 | 1.9 | 0.8673 |
| Get Nest Material | 64 | 1.7 | 1.0 | 12 | 0.1 | 0.1 | 0.5834 |
| Groom | 64 | 1.7 | 1.1 | 12 | 0.7 | 0.4 | 0.7503 |
| Active (while above ground) | 64 | 86.1 | 2.7 | 12 | 81.1 | 6.9 | 0.4594 |
| Forage (overall) | 64 | 39.2 | 3.6 | 12 | 12.0 | 5.3 | 0.0014 |
| Movements (m) | | | | | | | |
| Distance from Cover | 64 | 2.8 | 0.4 | 11 | 2.0 | 0.6 | 0.4065 |
| Distance to Burrow | 64 | 3.2 | 0.7 | 11 | 3.5 | 2.2 | 0.8733 |
| Distance Moved | 64 | 1.4 | 0.5 | 11 | 0.7 | 0.3 | 0.5624 |

[a] Analysis run on arcsine-transformed values of all proportions.

Table 3. Comparison of Townsend's ground squirrel (*Spermophilus townsendii*) behaviors (composing ≥ 1% of all observed behavior) and movements by month.

| Activity | February | | | March | | | April | | | May | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | n | Mean | SE | n | Mean | SE | n | Mean | SE | n | Mean | SE |
| Ingest Grass | 9 | 15.1 | 6.6A[a] | 10 | 19.0 | 4.9A | 39 | 31.3 | 5.0A | 18 | 28.9 | 5.3A |
| Vigilance | 9 | 36.4 | 7.0A | 10 | 34.8 | 10.4A | 39 | 25.1 | 4.7A | 18 | 18.2 | 5.7A |
| Sit | 9 | 13.8 | 4.5A | 10 | 9.7 | 4.5A | 39 | 8.1 | 2.5A | 18 | 3.5 | 1.9A |
| Bask | 9 | 0.0 | 0.0A | 10 | 4.2 | 4.2A | 39 | 4.4 | 2.2A | 18 | 16.5 | 7.0A |
| Ingest Forbs | 9 | 0.0 | 0.0A | 10 | 0.0 | 0.0A | 39 | 4.5 | 1.5A | 18 | 10.5 | 3.3A |
| Walk | 9 | 11.2 | 2.6A | 10 | 4.1 | 3.3A | 39 | 5.7 | 1.2A | 18 | 4.6 | 1.2A |
| In Burrow | 9 | 5.8 | 2.8A | 10 | 15.3 | 3.7A | 39 | 8.3 | 1.5A | 18 | 9.9 | 3.6A |
| Handle Food | 9 | 0.0 | 0.0A | 10 | 0.6 | 0.6A | 39 | 0.7 | 0.6A | 18 | 2.7 | 1.3A |
| Run | 9 | 5.8 | 1.7A | 10 | 2.2 | 1.1A | 39 | 3.4 | 1.1A | 18 | 1.3 | 0.5A |
| Dig for Food | 9 | 0.9 | 0.4A | 10 | 1.3 | 1.3A | 39 | 1.3 | 0.8A | 18 | 3.0 | 1.6A |
| Get Nest Material | 9 | 1.5 | 1.3A | 10 | 4.5 | 4.5A | 39 | 1.3 | 1.1A | 18 | 0.0 | 0.0A |
| Groom | 9 | 0.8 | 0.4A | 10 | 4.3 | 4.3A | 39 | 1.7 | 1.5A | 18 | 0.2 | 0.2A |
| Active (while above ground) | 9 | 86.2 | 4.5A[a] | 10 | 86.1 | 5.4A | 39 | 87.5 | 3.5A | 18 | 80.0 | 6.7A |
| Forage (overall) | 9 | 16.2 | 6.7A | 10 | 20.9 | 5.7A | 39 | 38.1 | 4.8A | 18 | 45.3 | 7.2A |
| Movement (m) | | | | | | | | | | | | |
| Distance to Cover | 8 | 2.9 | 1.3A | 10 | 2.9 | 1.0A | 39 | 2.6 | 0.5A | 18 | 2.7 | 0.6A |
| Distance to Burrow | 8 | 8.0 | 4.3A | 10 | 1.4 | 0.3B | 39 | 2.6 | 0.7B | 18 | 3.8 | 1.3AB |
| Distance Moved | 8 | 1.6 | 0.7A | 10 | 0.2 | 0.1A | 39 | 1.8 | 0.8A | 18 | 0.6 | 0.3A |

[a] Analysis run on arsine-transformed values of all proportions. Row values with same letter do not vary significantly at Bonferroni adjusted alpha of 0.003.

in the SRBOPA in both 1987 and 1988. Males are probably able to spend a greater proportion of their above-ground time foraging because they spend a smaller proportion being vigilant, although it is possible that a higher need for foraging drives this relationship. Although the difference in vigilance between the sexes was not significant ($\underline{P} = 0.0047$), the p-value is small enough to be of interest, especially since the difference isn't easily explained. Higher female vigilance may be related to protection of young while in the burrow and during the initial period following juvenile emergence. Sherman (1981) found a positive relationship between the number of female relatives nearby and alarm-calling in female Belding's ground squirrels (*Spermophilus beldingi*). Because males of this species disperse while females are more likely to be surrounded by close relatives, females are more likely to engage in such nepotistic behaviors. We do not yet have comparable information on dispersal of *S. townsendii*.

The higher rate of grass ingestion in burned habitats and the increase later in the year may be explained by a higher grass abundance in burned areas and the emergence of new grass during the growing season. The higher rate of vigilance and lower rate of basking on shrubby areas may be due to lower visibility of the surroundings. However, the differences between burned and shrubby habitats may not be as large as they appear because a high proportion of the activities were classified as unknown on shrubby areas. Because of poor visibility in shrubby areas, unknown activities comprised about 33% of the observations before being dropped for analysis, which could account for some of the observed differences.

## PLANS FOR NEXT YEAR

In the process of conducting this study and while livetrapping animals for the demographic study, we have observed that *S. townsendii* seem very sensitive to weather conditions, including wind, temperature, and insolation. These physiographic variables can change rapidly in the study area, and we think that activity patterns are closely linked to them. We plan to focus on the relationship between these variables and degree and type of activity. This information in combination with construction of some simple climate space models (Morhardt 1975) should allow us to predict activity patterns during given weather conditions with greater certainty, and may help us to interpret changes in activity associated with burning as well as tracking by armored vehicles. We also plan to use unique dye marks on some individuals so that activity budgets can be determined for known animals. Information on foraging will be interpreted in light of habitat-specific diet information as that information becomes available (see Van Horne et al., this volume). Finally, we plan to look at general differences in burrow morphology, at least in terms of the number of entrances per burrow, in the different habitat types.

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# Preliminary Report on Fat Dynamics of the Townsend's Ground Squirrel (*Spermophilus townsendii*)

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*Annual Summary*

*We used a total body composition analyzer to investigate variation in fat levels between juvenile Spermophilus townsendii from a population on a winterfat (Ceratoides lanata) site and a burned sagebrush (Artemisia tridentata) site, just prior to entry into torpor in June. Animals on the burned sagebrush site had higher levels of body fat, higher masses, and a lower percent lean mass. Percent body fat tended to be higher for females than for males on the winterfat sites, and higher for males than for females on the burned sage sites, although differences were nonsignificant. We also report on changes in body composition in animals maintained in the laboratory.*

## OBJECTIVES

1. To understand the role of fat deposition and use in the survival of male and female *Spermophilus townsendii* on the Snake River Birds of Prey Area (SRBOPA).

2. To determine whether there is variation in body fat content among and within habitat types.

3. To test whether differences in body fat content among juvenile *S. townsendii* influence over-winter survival, and whether any such relationship is consistent in different habitats.

4. To investigate the role of dietary differences among habitats in the accumulation of essential fatty acids.

## INTRODUCTION

Townsend's ground squirrels must accumulate sufficient fat during the January-June active period to survive the longer inactive period. This may be particularly difficult for juveniles, which emerge from their burrows at about 40 g in April and reach 250 to 300 g by the end of June (Van Horne et al., this volume), and for adult females which must produce a litter and lactate during the active period (Van Horne et al., this volume, Fig. 2).

Obtaining sufficient amounts of polyunsaturated fatty acids (PUFAs) in the diet may be particularly critical, since some PUFAs are essential nutrients (i.e., not synthesized in the body but required in the diet). Recent work suggests that PUFA accumulation in adipose stores is part of the survival strategy of hibernation during periods of resource shortage by reducing the metabolic cost of hibernation. PUFA composition of

diets affects PUFA composition in adipose stores (Florant et al. 1990). Experimental variation of dietary PUFA composition results in variation in body temperatures ($T_b$'s) of hibernating mammals (Geiser and Kenagy 1987, Frank 1991). Animals fed diets high in PUFAs hibernate at lower body temperatures and can tolerate lower ambient temperatures (Geiser and Kenagy 1987, Frank 1991), and arouse less frequently (Geiser and Kenagy 1987) than animals on low PUFA diets.

Overwinter mortality appears to be an important population parameter for *S. townsendii* in the SRBOPA (Smith and Johnson 1985). Townsend's ground squirrels do not include many seeds which are high in PUFAs in the prehibernation diet (Yensen, unpubl. data). Because vegetation varies among species in PUFA concentrations, PUFA accumulation may vary substantially among individual ground squirrels. If there are differences in overwinter mortality among habitats, or among individuals within habitats, these differences might well be mediated through differences in PUFA concentrations in the diet.

## METHODS

We used a total body composition analyzer, or TOBEC (Walsberg 1988, Castro et al. 1990), to measure body composition and, thus, fat deposition, in live ground squirrels. The TOBEC is based on the principle that predictable changes in conductivity associated with differences in body composition can be detected, by measuring differences in the impedance of a magnetic field generated by radiating coils. A regression describing this relationship is developed using fat extraction on sacrificed animals. Relationships thus established have a high predictive power ($R^2$ = 0.95+; see Castro et al. 1990, for example). We have collected 5 animals with large fat stores for this purpose; at least 10 more individuals will be required for developing the regression for *S. townsendii* (G. Castro, Manomet Bird Observatory, MA, pers. comm.). Body sizes do not affect the regression; fat levels do, and these will be varied in the sample. For the initial year's analysis, the regression developed for *Spermophilus saturatus* was used (J. Kenagy, Zoology Dept., Univ. Washington, Seattle, Washington, pers. comm.).

Tests of variation in fat accumulation were conducted on populations of *S. townsendii* on the SRBOPA in June 1991. Animals were live-trapped from pairs of sites with high (burned sagebrush) and low (winterfat) apparent food resource abundance, in the course of ongoing mark-recapture studies (Van Horne et al., this volume). Mass and body composition (using the TOBEC) of juveniles were measured.

The defense of fat depots during short-term fasts was tested in the laboratory with *S. townsendii* live-trapped from the SRBOPA near Coyote Butte. Twenty-four ground squirrels (2 adult males, 9 juvenile females and 13 juvenile males) were brought into captivity (Table 1). They were held under photoperiods reflecting natural conditions, adjusted 1 time each month, and at temperatures reflecting those at average burrow depths (Alcorn 1940, Reynolds and Wakkinen 1987). Ground squirrels demonstrated dramatic variations in mass in the first 2 months of captivity, and some individuals were tracked for body composition (using the TOBEC) during this time. Observed trends in fat deposition and mass changes are reported.

Twelve juvenile ground squirrels (6 males, 6 females) were used in fasting experiments to test whether fat stores are defended prior to the onset of seasonal torpor. They were held under photoperiod and temperature conditions as described above. Three ground squirrels of each sex were assigned at random to 1 of 2 treatment groups: laboratory chow, sunflower seeds, lettuce,

Table 1. Townsend's ground squirrels collected from the SRBOPA in May 1991 for captive study.

| Age/Sex | Number in captivity | Number monitored - peak to minimum mass | Number monitored - minimum to stabilized mass | Number used in fasting experiment |
|---|---|---|---|---|
| Adult male | 2 | 1 | 1 | 0 |
| Juvenile male | 13 | 9 | 7 | 6 |
| Juvenile female | 9 | 6 | 3 | 6 |

and water ad lib; or only water ad lib. Animals were fasted for 1 week, then allowed to refeed until masses returned to prefasting levels for the majority of individuals in the fasted treatment group. Mass and body composition were measured at the beginning of the experiment, after 1 week of fasting, and at the end of the experiment. Significance of statistical analyses was indicated at $P < 0.05$.

## RESULTS AND SIGNIFICANCE OF FINDINGS

Preliminary results indicated that there is significant variation in fat accumulation in the wild among individuals within each sex class and between sites (Table 2). Juvenile ground squirrels from burned sage sites had larger body masses (d.f. = 1,52; $F = 4.392$, $P = 0.041$), more grams of fat accumulated (d.f. = 1,51; $F = 8.701$, $P = 0.005$), and a greater percent of body mass composed of fat than juvenile squirrels from winterfat sites (d.f. = 1,51; $F = 10.363$, $P = 0.002$). However, accumulation of lean mass did not differ between site types (d.f. = 1,51; $F = 0.119$, $P = 0.732$; Table 2). Although total mass, lean mass, and fat mass varied significantly between males and females (total mass: d.f. = 1,51; $F = 69.482$, $P < 0.001$; lean mass: d.f. = 1,51; $F = 64.098$, $P < 0.001$; fat mass: d.f. = 1,51; $F = 16.894$, $P < 0.001$), percent of mass composed of fat was not significantly different by sex; only site differences were significant in this regard. On the winterfat sites, females tended to have a higher percent body fat, while the reverse was true on the burned sage sites (Table 2).

Captive *S. townsendii* gained weight and fat dramatically over the first month of captivity, then lost significant weight while being fed ad libitum. Body composition changes during this time indicate that both fat and protein were lost, and more fat than protein was lost (Table 3). This accumulation and subsequent decline in mass may be the endogenous pattern of fat accumulation and use in these hibernators.

Fasted animals lost mostly fat (Table 4, Fig. 1), as would be predicted in a fasted non-hibernator. This suggests that Townsend's ground squirrels do not defend fat stores prior to hibernation, or that animals had entered the season of fat depletion even though they were not torpid.

## FUTURE PLANS

We plan to expand the field portion of this study to 6 sites, 3 burned sites and 3 native shrub sites, and follow fattening and survival patterns for 2 consecutive years. Since juveniles have the greatest overwinter mortality (Smith and Johnson 1985), we will test hypotheses among juveniles of both

Table 2. Body composition (+/- SE) of juvenile *Spermophilus townsendii* prior to estivation.

| Site Type | Site No. | Sex | N | Grams Mass | % Lean | Grams Lean | % Fat | Fat |
|---|---|---|---|---|---|---|---|---|
| Winterfat | 1a | male | 5 | 233.8 (15.2) | 178.9 (6.6) | 77.7 (5.2) | 54.9 (13.9) | 22.3 (5.2) |
| | | female | 3 | 188.3 (7.3) | 141.5 (4.0) | 75.2 (0.8) | 46.8 (3.2) | 24.8 (0.8) |
| | 1b | male | 1 | 206.0 | 180.9 | 87.8 | 25.1 | 12.2 |
| | | female | 3 | 163.7 (4.5) | 134.9 (3.9) | 82.4 (1.6) | 28.8 (3.0) | 17.6 (1.6) |
| | all | male | 6 | 229.2 (13.2) | 179.2 (5.4) | 79.4 (4.5) | 49.9 (12.4) | 20.6 (4.5) |
| | | female | 6 | 176.0 (6.7) | 138.2 (2.9) | 78.8 (1.8) | 37.8 (4.5) | 21.2 (1.8) |
| Burned sage | 4a | male | 5 | 250.2 (7.7) | 177.7 (7.0) | 71.0 (1.2) | 72.5 (3.1) | 29.0 (1.2) |
| | | female | 6 | 169.7 (4.6) | 132.0 (2.5) | 77.8 (1.6) | 37.7 (3.5) | 22.1 (1.6) |
| | 4b | male | 16 | 251.6 (7.5) | 171.8 (4.8) | 68.6 (1.6) | 79.8 (5.7) | 31.4 (1.6) |
| | | female | 16 | 189.2 (2.7) | 144.4 (2.4) | 76.2 (1.1) | 45.4 (2.6) | 23.8 (1.1) |
| | all | male | 21 | 251.3 (5.9) | 173.2 (4.0) | 69.2 (1.2) | 78.1 (4.4) | 30.8 (1.2) |
| | | female | 22 | 184.1 (2.9) | 141.0 (2.2) | 76.7 (0.9) | 43.3 (2.2) | 23.3 (0.9) |

Table 3. Changes in body composition of *Spermophilus townsendii* held in captivity.

A. Changes between peak and minimum weights; SE in parentheses.

| Time | Age | Sex | N | Mass | Grams lean | % lean | Grams fat | % fat |
|---|---|---|---|---|---|---|---|---|
| peak weight | juv. | male | 9 | 260.2 (12.6) | 153.8 (7.0) | 59.4 (1.4) | 106.4 (7.4) | 40.6 (1.4) |
| | juv. | female | 6 | 220.2 (11.3) | 139.5 (5.3) | 63.6 (1.3) | 80.7 (6.4) | 36.4 (1.3) |
| | ad. | male | 1 | 281.0 | 144.1 | 51.3 | 136.9 | 48.7 |
| minimum weight | juv. | male | 13 | 216.4 (7.9) | 132.3 (1.7) | 61.9 (1.9) | 84.1 (6.8) | 38.1 (1.9) |
| | juv. | female | 9 | 175.4 (7.3) | 122.1 (1.0) | 70.4 (2.6) | 53.3 (6.4) | 29.6 (2.6) |
| | ad. | male | 1 | 266.2 | 154.5 | 58.0 | 111.7 | 42.0 |

B. Changes between minimum weights and stabilized weights for individuals not used in fasting experiments; SE in parentheses.

| Time | Age | Sex | N | Mass | Grams lean | % lean | Grams fat | % fat |
|---|---|---|---|---|---|---|---|---|
| minimum | juv. | male | 7 | 198.9 (9.7) | 131.1 (3.1) | 66.6 (2.3) | 67.7 (7.5) | 33.4 (2.3) |
| | juv. | female | 3 | 149.7 (6.2) | 118.5 (0.7) | 79.4 (3.0) | 31.3 (6.0) | 20.6 (3.0) |
| | ad. | male | 1 | 266.2 | 154.5 | 58.0 | 111.7 | 42.0 |
| stabilized | juv. | male | 7 | 210.5 (9.5) | 131.3 (3.1) | 62.8 (1.8) | 79.3 (7.0) | 37.2 (1.8) |
| | juv. | female | 3 | 153.8 (4.0) | 118.1 (1.1) | 76.9 (1.3) | 35.7 (2.9) | 23.1 (1.3) |
| | ad. | male | 1 | 268.8 | 148.5 | 55.2 | 120.3 | 44.8 |

Table 4. Mass and body composition of *Spermophilus townsendii* fasted or fed ad lib.

| Treatment | Mass grams | SE | Lean mass grams | (SE) | % | Fat grams | (SE) | % |
|---|---|---|---|---|---|---|---|---|
| Day 0 | | | | | | | | |
| Fasted males | 243.6 | 9.6 | 134.9 | (1.2) | 55.5 | 108.6 | (8.9) | 44.5 |
| Fasted females | 191.5 | 6.0 | 123.9 | (1.2) | 64.8 | 67.65 | (6.0) | 35.2 |
| Ad lib males | 228.5 | 6.8 | 130.8 | (1.9) | 57.3 | 97.6 | (5.7) | 42.7 |
| Ad lib females | 182.7 | 4.1 | 123.9 | (0.6) | 67.9 | 58.8 | (3.7) | 32.1 |
| Day 8 | | | | | | | | |
| Fasted males | 205.7 | 9.5 | 125.7 | (0.4) | 61.4 | 79.9 | (9.2) | 38.6 |
| Fasted females | 156.6 | 6.4 | 116.1 | (0.4) | 74.4 | 40.5 | (6.1) | 25.6 |
| Ad lib males | 225.4 | 7.9 | 135.5 | (1.4) | 60.3 | 89.8 | (9.2) | 39.7 |
| Ad lib females | 189.2 | 9.9 | 126.5 | (2.6) | 67.1 | 62.7 | (7.4) | 32.9 |
| Day 20 | | | | | | | | |
| Fasted males | 237.8 | 14.3 | 139.1 | (4.1) | 58.8 | 98.7 | (12.4) | 41.2 |
| Fasted females | 186.5 | 4.3 | 125.5 | (1.3) | 67.3 | 61.1 | (4.9) | 32.7 |
| Ad lib males | 221.0 | 9.4 | 131.5 | (1.8) | 59.7 | 89.6 | (9.9) | 40.3 |
| Ad lib females | 188.9 | 8.5 | 124.5 | (2.1) | 66.1 | 64.4 | (6.4) | 33.9 |

sexes. We will also examine differences in PUFA levels in diets of *S. townsendii* from different sites. Animals will be collected so that we can determine the appropriate regression for the body composition analysis. Laboratory studies will be continued in order to investigate fat dynamics during hibernation more closely.

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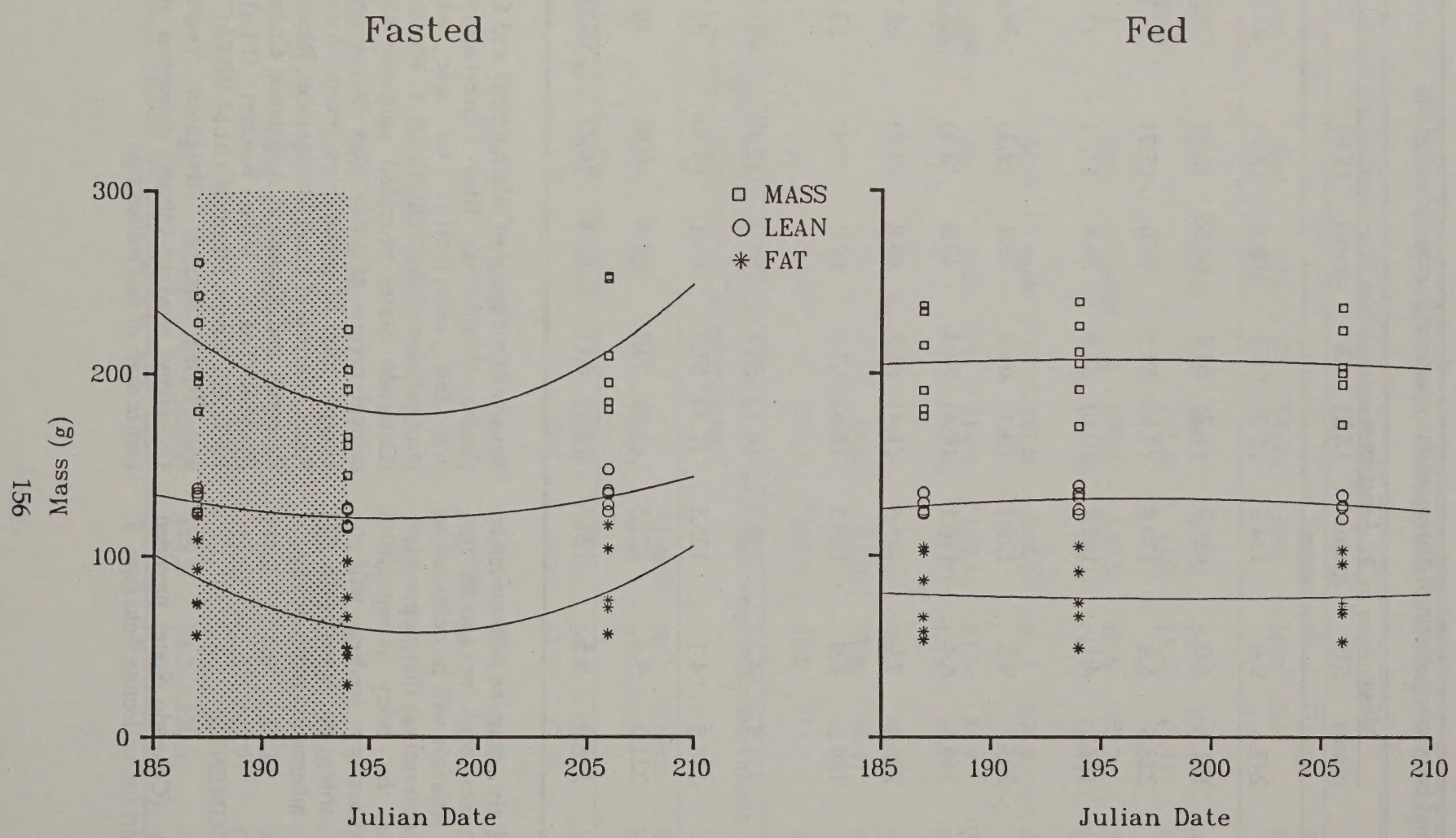


Fig. 1. Body composition changes of *Spermophilus townsendii* either fasted or fed ad lib. Shaded area indicates fasting.

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# Habitat Classification and the Ability of Habitats to Support Populations of Townsend's Ground Squirrels and Black-tailed Jackrabbits

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*Annual Summary*

*Indexes of Townsend's ground squirrel (Spermophilus townsendii) populations averaged 169.0 total burrows/ha (125.4 active; 43.6 inactive) for 115 sites randomly sampled throughout the Integration Study Area (ISA) and Orchard Training Area (OTA), located within the Snake River Birds of Prey Area (SRBOPA). Number of burrows was correlated with East and North UTM coordinate, % bare ground, % moss, and % grass. Burrow numbers were positively correlated with Sandberg's bluegrass (Poa secunda) and six-weeks fescue (Festuca octoflora) and negatively correlated with Russian thistle (Salsola iberica). Number of burrows was not related to presence of military vehicle tracking or livestock grazing. We also counted 133.1 burrows/ha (89.8 active; 45.4 inactive) for 53 historical transects in the SRBOPA. Burrow counts on historical transects were the highest since 1987.*

*North UTM coordinate explained 51.8% of the variation in the first axis and East UTM coordinate explained 24.3% of the variation in the second axis in a principal components analysis of vegetation sampled at 115 randomly located sites. Percent cover of bur buttercup (Ranunculus testiculatus), peppergrass (Lepidium perfoliatum), and Russian thistle was higher in transects that had military tracking while percent cover of big sage (Artemisia tridentata), cheatgrass (Bromus tectorum), and crested wheatgrass (Agropyron cristatum) was lower. Percent cover of bur buttercup, cheatgrass, peppergrass, Sandberg's bluegrass, six-weeks fescue, and tall tumblemustard (Sisymbrium altissimum) was higher in transects north of the grazing drift fence while percent cover of winterfat (Ceratoides lanata) was lower in transects north of the drift fence.*

*Densities of black-tailed jackrabbits (Lepus californicus) along spotlight transect routes were estimated at 0.16/ha (0.14-0.19, 95% C.I.) during winter 1990-91, and at 0.15 (0.12-0.18, 95% C.I.) on new transects and 0.22 (0.19-0.25, 95% C.I.) on historical transects in spring 1991. Densities of jackrabbits continued to decline for the second year after the cyclic peak in 1989. Jackrabbit densities were higher for transects sampled in the OTA compared to transects outside the OTA for both winter and spring surveys. Densities of jackrabbits were higher on transects located south of the drift fence compared to transects north of the fence for both winter and spring surveys. I also observed 20 Nuttall's cottontails (Sylvilagus nuttallii), 2 pygmy rabbits (Brachylagus idahoensis), 862 kangaroo rats (Dipodomys ordii and D. microps), and 24 mice and voles on spotlight transects.*

## OBJECTIVES

1. To assess influence of military activities and livestock use on habitats and abundance of Townsend's ground squirrels and black-tailed jackrabbits.

2. To determine habitat correlates of Townsend's ground squirrel abundance and establish permanent transects that will be resampled at specified intervals for long-term monitoring of vegetation and Townsend's ground squirrels.

3. To monitor the relative abundance of Townsend's ground squirrels on transects established in 1982 within the Snake River Birds of Prey Area.

4. To estimate jackrabbit densities from night spotlight counts along historical and newly established transects.

5. To record all sightings of Nuttall's cottontail rabbits, pygmy rabbits, kangaroo rats, and mice and voles (combined) on spotlight transects.

## INTRODUCTION

Abundant populations of Townsend's ground squirrels (*Spermophilus townsendii*) and black-tailed jackrabbits (*Lepus californicus*) are needed to maintain one of the world's highest densities of nesting raptors in the Snake River Birds of Prey Area (SRBOPA) (U.S. Dep. Inter. 1979, Steenhof and Kochert 1988). In recent years, public concerns were raised that intensive grazing (Yensen 1980), extensive wildfires (Kochert and Pellant 1986), and long-term military activities in the Orchard Training Area (OTA) had influenced habitat and prey communities in the SRBOPA. The purpose of Study 5 of the Bureau of Land Management/Idaho Army National Guard Research Project (BLM/IDARNG) is to evaluate the influence of these activities and provide an accurate description and spatial delineation of habitats and prey communities within the SRBOPA.

## METHODS

### Townsend's Ground Squirrels and Habitats

Selection of Random Sampling Locations.--I sampled habitats and prey within the Integration Study Area (ISA) of the SRBOPA, including the OTA. One thousand sites within the ISA were randomly selected; number of sites was apportioned between the ISA and the OTA relative to their respective areas (ha). In 1991, we sampled 115 of the first 200 in the 1,000 potential sample points. All sites were marked in the field by metal fence posts and their position recorded by a Global Positioning System for future studies of long-term changes (e.g., Anderson and Holte 1981, Turner 1990).

Townsend's Ground Squirrels.--The number of Townsend's ground squirrel burrows was counted in 5 x 400-m transects (Fig. 1) at the end of the active season for squirrels from 10 June through 1 August. An observer recorded all active and inactive ground squirrel and badger (*Taxidea taxus*) burrows in the strip. Criteria to distinguish active burrows from inactive included absence of wind-blown debris or spider webs, presence of claw marks or feces at the burrow, presence of trails emanating from the burrow, observation of squirrels, or absence of plant roots from burrow ceiling (Peterson and Yensen 1986, Wheeler et al. 1989). I attempted to discern activity status for the current season, rather than the more

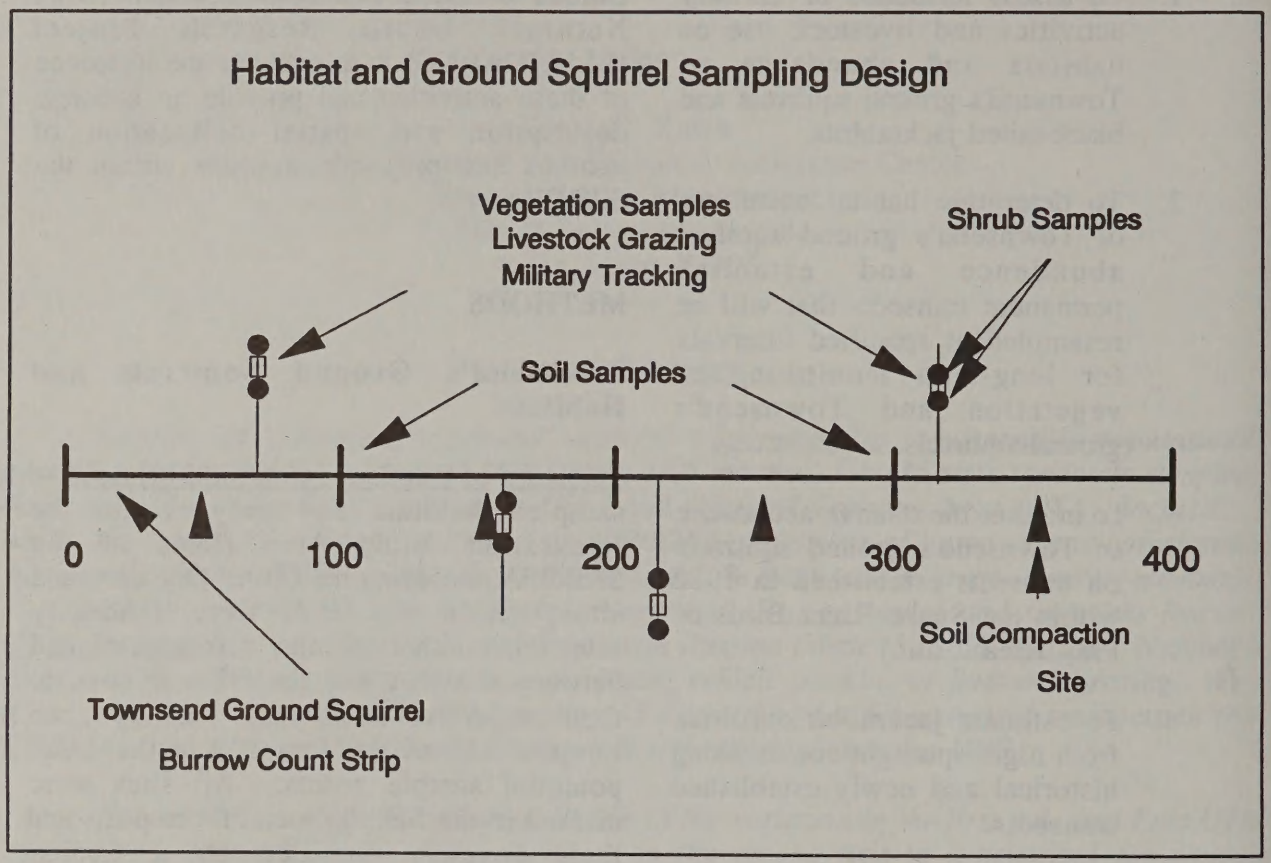


Fig. 1. Design for sampling habitat and Townsend's ground squirrel burrows at randomly located sites.

restrictive sampling criteria used in Study 4 that defined active to include only at the time of sampling (Van Horne et al., this volume).

Yearly sampling also was continued on 53 of 54 previously established 400 x 5-m strip transects to permit calibration and reference to previous research (Peterson and Yensen 1986, Wheeler et al. 1989). I did not sample 16 transects previously established to monitor effects of burns in shadscale (*Atriplex confertifolia* ) habitats (Groves and Steenhof 1988) and 11 transects in seeded areas (Quinney et al. 1987). We were unable to locate 1 historical transect (Transect #21) in both 1990 and 1991. Densities of active, inactive, and total burrows were compared between random and historical transects by Student's t test (PROC TTEST, SAS Statistical Institute 1988).

Vegetation.--Vegetation, soils, and military and grazing information were sampled on $\geq 4$ 50-m transects perpendicular to the center line of the 400-m strip transect (Fig. 1, Table 1). At least 1 50-m transect was randomly

Table 1. Variables measured on strip transects for counting burrows of Townsend's ground squirrels.

| Variable | Data Type |
|---|---|
| No. TGS Burrows | Continuous |
| No. Badger Burrows | Continuous |
| Plant Species | Diversity index; Species richness |
| Food Items | Percent |
| Plant Species Cover | Percent |
| Canopy Cover | Percent |
| Bare Ground | Percent |
| Shrub Height | Continuous |
| Height to Canopy | Continuous |
| Presence/absence canopy | Binomial |
| Soil Texture | Continuous |
| Soil Depth | Continuous |
| Soil % Organic | Percent |
| Soil % Nitrates | Percent |
| No. cow fecal pats | Continuous, categorical, or binomial |
| No. sheep feces | Continuous, categorical, or binomial |
| No. Livestock Tracks | Percent cover |
| Pocket gopher mound | Percent cover |
| No. tank tracks | Percent cover, categorical, or binomial |

located within each 100-m segment (Fig. 1). Therefore, each site effectively sampled a 100 x 400-m area (4 ha).

I sampled vegetation (species composition, frequency, canopy cover, % bare ground) by point intercept (Floyd and Anderson 1982) from 1 5-m section at randomly-determined points on each 50-m transect (Fig. 1). The sample unit consisted of 1 5-m section. The number of sample units with single 5-m sections needed to determine vegetation characteristics was assessed in the field by calculating a running mean of the 4 most abundant categories (Grieg-Smith 1983) and ranged from 7-11. . Additional transects needed to obtain a stabilized mean were added at randomly-selected points along the entire 400-m burrow count transect.

When shrubs were present, shrub density, mean shrub height, mean shrub height from ground to canopy, and presence/absence of canopy was determined from 20-$m^2$ (2.52-m radius) plots (Asherin 1973). The number of shrubs needed for sampling was calculated from a running mean. Shrub plots were established at each end of the 5-m sections for vegetation sampling by point frame (Fig. 1).

Species richness ($\underline{S}$, number of species present) and species diversity were determined for total species composition at a sampling site. The diversity index was $\underline{H} = 1/\sum p_i^2$ where $p_i$ was the proportion of the $\underline{i}$th species in the total sample ($\underline{N}_i/\underline{N}$) (Hill 1973, May 1981). This index equaled 1 when a single species dominated

the sample; higher values resulted from increasing number of species and evenness of distribution.

Habitat class was assigned to each transect based on the classification scheme developed from previous vegetation surveys (Table 2) (Knick et al., this volume).

I also used grouped classes for shrubs (Class IA and IB), grasses (Class IIA and IIB), and disturbed (Class IC and IIC) sites in the analyses.

Table 2. Initial habitat classes determined from vegetation surveys on the Snake River Birds of Prey Area from 1987-1990. Vegetation composition of each habitat type is presented in Knick et al. (this volume).

I. Shrubland
- A. Low disturbance
  1. shadscale + perennial grasses, native forbs
  2. shadscale + winterfat
  3. winterfat
  4. sagebrush + winterfat
  5. sagebrush (high density) + perennial grasses, native forbs
  6. greasewood
  7. saltbush
  8. gray rabbitbrush
- B. High disturbance
  1. shadscale + BRTE + SAKA[a]
  2. sagebrush (medium density) + BRTE, perennial grasses
  3. green rabbitbrush
  4. reseeding - shrubs
- C. Extreme disturbance
  1. sagebrush (low density) + SAKA
  2. SAKA
  3. SAKA + BRTE

II. Grassland
- A. Low disturbance
  1. native perennial grasses
- B. High disturbance
  1. perennial grasses + exotic annual (esp. SAKA)
  2. reseeding - bunchgrass
- C. Extreme disturbance
  1. BRTE (+ mustards)
  2. bare ground (including roads)

III. Artificial
- A. High disturbance
  1. agricultural (including fallow)
- B. Extreme disturbance
  1. "urban" (buildings, constructions, and their surroundings)

IV. Other
- A. Low disturbance
  1. riparian
  2. water
  3. rock

[a] BRTE = cheatgrass, SAKA = Russian thistle.

Soils.--Soil samples were collected at the 100 and 300-m points along the burrow count transect (Fig. 1). At each point, we collected samples from the surface and at a 1-m depth to determine soil texture. Soil samples were sent to the University of Idaho for analysis of soil texture, % organic content, and % nitrates.

Military Use.--Tracking intensity was determined by categorical estimation (presence = 1; absence = 0) of military tracks along each 100-m segment of the 5-m wide transect line. Percent cover of tracks was also determined from point frame counts. Samples were grouped into shrub (Class IA and IB), and grass (Class IIA, IIB, and IIC) classes. Influence of military tracking on the number of burrows was compared between tracked and untracked sites by a 2-way ANOVA (PROC GLM, SAS Statistical Institute 1988) for habitats, tracking, and a habitat*tracking interaction.

Relationship of military tracking to vegetation species was determined by a series of Student's t tests (PROC TTEST, SAS Statistical Institute 1988). Sites were grouped based on presence or absence of military tracking.

Livestock Use.--At each burrow count transect, a categorical estimate (presence = 1; absence = 0) of cattle and sheep use was obtained along each 100-m segment (Fig. 1) from presence of fecal material, or tracks. Percent cover of livestock litter was determined from point frame counts.

Relationship of livestock presence on the number of burrows was compared between randomly-selected sites with presence of livestock to sites without livestock presence by a 2-way ANOVA (SAS Proc GLM, SAS Statistical Institute 1988) for habitat, livestock, and habitat*livestock interactions. Sites were grouped into shrub and grass classes.

Relationship of grazing season on vegetation was compared for sites north or south of the drift fence by Student's t tests (PROC TTEST, SAS Statistical Institute 1988). The drift fence is a boundary between winter (south of the fence) and spring-fall (north of the fence) grazing periods.

Statistical Analysis of Ground Squirrels and Habitats.--I used a series of statistical analyses in an exploratory attempt to find the best association between the number of ground squirrel burrows and the habitat. The analyses included both direct and indirect gradient analyses. In direct gradient analysis, the abundance of a species is compared directly to single or multiple habitat variables (Gauch 1982). In indirect analysis, ordinations reduce the dimensionality to 1 or more axes that summarize all variation in the set of habitat variables against which the abundance of a species is subsequently compared (Gauch 1982, ter Braak and Prentice 1988).

The separate statistical analyses contained some redundancy, although each had different emphases. In direct gradient analysis, linear and multiple regressions stressed the direct linear relationship between the number of burrows and 1 or more habitat variables. Linear regression also was used to reduce the data set (Montgomery and Peck 1982) to variables that were significant in explaining the number of ground squirrel burrows. Indirect gradient statistics first emphasized the relationship among the habitat variables that was later regressed against a species abundance or another external variable. For indirect gradient analyses, I used both principal components and detrended correspondence analyses. In principal components analysis, the variation within the entire set of habitat variables was summarized by linear vectors. The first component axis was the linear vector that described the most variation in the set of

habitat variables, followed by subsequent linear axes in order of the amount of variation that was explained by each axis. In detrended correspondence analysis, the relationship of habitat variables also is summarized along axes that represent major sources of variation. However, the response is assumed to be unimodal or nonlinear, rather than a linear vector as in principal components analysis (Gauch 1982, ter Braak 1985).

Counts of ground squirrel burrows were transformed by sqrt($\underline{x}$ + 0.5), and percentage variables were transformed by arcsine (sqrt $\underline{x}$) to obtain a normal distribution before analysis (Sokal and Rohlf 1981). Distributions of all variables were tested for normality by the Shapiro-Wilk statistic (PROC UNIVARIATE, SAS Statistical Institute 1988). When normality was rejected even after transformation, I used the case that most approximated a normal distribution.

The number of ground squirrel burrows was first compared between habitats by a 1-way ANOVA (PROC GLM, SAS Statistical Institute 1988) to determine if any habitat type from our classification (Table 2) supported different numbers of ground squirrels. I used Fisher's protected least significant differences procedure to separate significantly different class means (Steele and Torrie 1980). Habitat classes with < 5 observations were omitted from the analysis.

The number of ground squirrel burrows was compared with all individual variables, independent of habitat type, by linear regression (PROC REG, SAS Statistical Inst. 1988) to determine which variables were significantly related. These variables included east and north UTM coordinates, vegetation groups (shrub, forb, and grass) and individual species, and presence of livestock or military tracking. Variables with significant correlations were retained for further analysis in a multiple linear regression (PROC GLM, SAS Statistical Institute 1988).

I used a principal components analysis (Morrison 1976; PROC PRINCOMP, SAS Statistical Institute 1988) to extract linear vectors that summarized the most variation in the complete set of habitat variables, excluding geographic variables. The number of burrows and North and East UTM coordinate were subsequently regressed against the principal axes.

I also summarized the environmental variation for the random sample sites in a nonlinear analyses by using a detrended correspondence analysis (CANOCO, ter Braak 1988) of the percent cover of vegetation species. Relationships between the number of burrows, and North and East UTM coordinates with the first 3 ordination axes were determined by subsequent linear and unimodal regression models (ter Braak and Prentice 1988).

**Black-tailed Jackrabbits**

Jackrabbits were counted by spotlight at night between 2200 and 0500 hr (Smith and Nydegger 1985) by driving along previously established transects (Doremus et al. 1989). Winter surveys were conducted on historical transects between November and December 1990. Spring surveys for all but 1 route were between 20 May and 16 June; the remaining transect was surveyed on 27 June 1991. Each transect was driven 2 times on separate nights during each survey period except for the Range 3 transect, which was not sampled in the winter survey.

Seven new transects (68.28 total km, range 2.3 - 19.1 km) were added to the 14 historical transects for the spring surveys. Transects were selected in unsampled regions and consisted of single-track jeep roads with vegetation along the centerline (Smith and Nydegger 1985). New transects

largely included grass or burned habitats that have not historically supported high densities of jackrabbits (Knick 1990). Because of potential differences in density estimates, I compared the distribution of sighting distances and the density estimates between new and historical transects before pooling data for analysis of population trend. Mean location of sample distances obtained on new and historical transects was compared by Wilcoxon 2-sample test (PROC NPAR1WAY, SAS Statistical Institute 1988) and their distribution by Kolmogorov-Smirnov 2-sample test (PROC NPAR1WAY, SAS Statistical Institute 1988) to determine if detection differences were present. Density estimates from new and historical transects were then compared by $z$ test.

Density of jackrabbits was estimated using program DISTANCE (Laake et al. 1991), an upgraded version of the program TRANSECT (Burnham et al. 1980). The model estimator (half-normal, uniform, negative exponential, hazard) that produced the best fit (Chi Square Goodness of Fit) was used for analysis of distance data.

I compared estimates of jackrabbit densities between OTA and non-OTA transects north of the Snake River to determine regional differences based on presence of military training. I also compared jackrabbit densities for north and south of the drift fence to determine regional differences relative to season of livestock grazing. Regional comparisons were done separately for winter and spring surveys.

Habitat types were not determined along transects but will be examined when an accurate GIS layer of vegetation for the SRBOPA is produced (Knick et al., this volume). We recorded habitat at each sighting (Table 2) and a categorical estimate of distance to nearest shrub cover for future comparison with habitat availability.

Sightings of kangaroo rats, Nuttall's cottontail rabbits, pygmy rabbits, and mice and voles also were recorded on black-tailed jackrabbit spotlight transects. The number of sightings was not converted into a density estimate for these species.

## RESULTS

### Townsend's Ground Squirrels and Habitats

We sampled 87 randomly located sites within the ISA and 28 in the OTA for Townsend's ground squirrels and habitat. In addition, burrows were counted on 53 of 54 historical transects in the SRBOPA (Table 3). We were unable to locate transect #21 in both 1990 and 1991.

Indexes of Townsend's ground squirrel populations averaged 169.0 $\pm$ 15.8 ($\underline{x} \pm$ S.E.) total burrows/ha (125.4 $\pm$ 12.6 active; 43.6 $\pm$ 5.0 inactive) for 115 sites randomly located throughout the ISA and OTA. Counts of burrows averaged 133.1 $\pm$ 21.2 burrows/ha (87.7 $\pm$ 14.2 active; 45.4 $\pm$ 8.9 inactive) for 53 historical transects in the SRBOPA. The historical transects had a significantly lower number of total ($\underline{t}$ = 1.79, $\underline{P}$ = 0.08) and active ($\underline{t}$ = 2.32, $\underline{P}$ = 0.02) burrows compared to the newly established transects. The number of inactive burrows was similar between historical and new transects ($\underline{P} >$ 0.10). The total number of burrows counted on historical transects was the highest since 1987 and was 4 times higher than in 1990.

Plant species richness ranged from 2 to 15 for randomly-selected sites. Diversity ranged from 1.02 to 5.30. $\underline{S}$ and $\underline{H}$ were similar between shrub, grass, and disturbed habitats as well as within individual habitat classes (ANOVA, $\underline{P} > 0.10$).

Table 3. Density of Townsend's ground squirrel burrows (n/ha) on 54 established transects in the Snake River Birds of Prey Area. Counts were obtained from 5 X 400 m transects using strip transect methodology. Data from 1982-1989 are from Wheeler et al. 1989). Habitat descriptions for each site are given in Wheeler et al. (1989).

| Transect | 1982 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|---|
| 4 | 735 | 315 | 505 | 455 | 410 | 135 | 330 |
| 5 | 131 | 230 | 320 | 55 | 85 | 160 | 330 |
| 6 | 232 | 180 | 240 | 80 | 65 | 75 | 215 |
| 7 | 373 | 260 | 645 | 225 | 175 | 65 | 260 |
| 13 | 624 | 370 | 120 | 275 | 210 | 15 | 210 |
| 14 | 342 | 100 | 250 | 315 | 185 | 20 | 120 |
| 15 | 453 | 150 | 625 | 295 | 265 | 15 | 65 |
| 16 | 322 | 340 | 470 | 255 | 235 | 0 | 190 |
| 17 | 201 | 130 | 95 | 50 | 85 | 5 | 105 |
| 18 | 322 | 340 | 230 | 120 | 100 | 15 | 55 |
| 20 | 60 | 55 | 55 | 80 | 50 | 0 | 85 |
| 21 | 60 | 25 | 105 | 95 | 115 | ---[a] | ---[a] |
| 22 | 483 | 35 | 70 | 50 | 35 | 20 | 70 |
| 23 | 70 | 40 | 95 | 85 | 85 | 30 | 15 |
| 24 | 131 | 35 | 55 | 65 | 40 | 25 | 10 |
| 26 | 584 | 5 | 170 | 80 | 165 | 140 | 265 |
| 33 | 101 | 70 | 155 | 60 | 70 | 135 | 335 |
| 34 | 242 | 30 | 55 | 35 | 25 | 45 | 15 |
| 35 | 322 | 120 | 195 | 25 | 135 | 225 | 250 |
| 50 | 393 | 105 | 115 | 60 | 70 | 70 | 215 |
| 51 | 111 | 45 | 30 | 50 | 45 | 45 | 125 |
| 53 | 121 | 15 | 15 | 20 | 15 | 0 | 10 |
| 54 | 201 | 15 | 30 | 0 | 0 | 10 | 75 |
| 55 | 262 | 20 | 145 | 5 | 150 | 15 | 130 |
| 56 | 363 | 270 | 560 | 170 | 200 | 35 | 135 |
| 57 | 201 | 180 | 330 | 170 | 230 | 25 | 270 |
| 121 | 121 | 170 | 110 | 80 | 115 | 25 | 35 |
| 122 | 0 | 0 | 0 | 0 | 25 | 0 | 5 |
| 123 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 124 | 20 | 25 | 15 | 0 | 5 | 0 | 5 |
| 125 | 0 | 0 | 10 | 0 | 30 | 0 | 0 |
| 126 | 0 | 0 | 5 | 0 | 0 | 0 | 0 |
| 127 | 252 | 0 | 15 | 0 | 0 | 5 | 5 |
| 128 | 50 | 0 | 15 | 30 | 0 | 0 | 0 |
| 147 | 101 | 5 | 30 | 15 | 5 | 0 | 0 |
| 148 | 50 | 5 | 10 | 5 | 5 | 0 | 0 |
| 149 | 111 | 0 | 5 | 0 | 10 | 20 | 0 |
| 150 | 10 | 5 | 0 | 0 | 5 | 0 | 0 |
| 151 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 152 | 30 | 0 | 10 | 0 | 0 | 0 | 0 |
| 161 | 10 | 0 | 20 | 15 | 15 | 0 | 0 |
| 162 | 232 | 30 | 30 | 20 | 35 | 0 | 0 |
| 165 | 30 | 60 | 60 | 60 | 60 | 0 | 30 |
| 172 | 141 | 90 | 115 | 65 | 100 | 20 | 60 |
| 182 | 50 | 30 | 5 | 10 | 20 | 0 | 0 |
| 183 | 40 | 0 | 65 | 5 | 0 | 0 | 0 |
| 200 | 222 | 25 | 100 | 20 | 60 | 85 | 170 |
| 201 | 332 | 20 | 830 | 0 | 5 | 30 | 155 |
| 202 | 796 | 75 | 725 | 15 | 100 | 20 | 140 |
| 203 | 70 | 65 | 100 | 65 | 70 | 14 | 15 |
| 204 | 50 | 20 | 30 | 30 | 35 | 5 | 60 |
| 205 | 141 | 10 | 35 | 20 | 0 | 10 | 35 |
| 206 | 81 | 15 | 55 | 25 | 25 | 0 | 40 |
| 207 | 60 | 0 | 30 | 0 | 10 | 5 | 10 |
| Total | 10,460 | 4,130 | 8,105 | 3,655 | 3,955 | 1,575 | 4,650 |
| Mean | 193.3 | 76.5 | 150.1 | 67.7 | 73.2 | 30.0 | 89.8 |

[a] Transect 21 was not located in 1990 or 1991.

Military Use.--Number of burrows of Townsend's ground squirrels was not significantly different between presence or absence of military tracking ($F = 0.19$, $P = 0.91$) for the randomly-selected sites (Table 4).

Percent cover of bur buttercup (*Ranunculus testiculatus*), peppergrass (*Lepidium perfoliatum*), and Russian thistle was higher in transects that had military tracking compared to untracked transects (Table 5). Percent cover of big sage (*Artemisia tridentata*), cheatgrass (*Bromus tectorum*), crested wheatgrass (*Agropyron cristatum*) was lower on transects that had military tracking (Table 5).

Livestock Use.--The number of burrows was not significantly different between sites that had evidence of livestock compared to sites with an absence of livestock (tracks or fecal pats along the transect center) ($F = 0.22$, $P = 0.89$) (Table 4).

Percent cover of bur buttercup, cheatgrass, peppergrass, Sandberg's bluegrass, six-weeks fescue, and tall tumblemustard (*Sisymbrium altissimum*) was higher in transects north of the grazing drift fence (Table 6). Percent cover of winterfat (*Ceratoides lanata*) was lower in transects north of the drift fence (Table 6).

Townsend's Ground Squirrel Abundance and Habitats.--Habitats differed in the number of active ($F = 2.31$, $P = 0.03$) and total ($F = 2.41$, $P = 0.03$) burrows counted on transects. The number of active and total burrows were significantly higher in habitats with perennial grasses (Habitat class IIB2, Table 2) and lower in habitats dominated by Russian thistle (Class IC2, Table 2) (Table 7). All other habitats had a similar number of burrows. Total number of ground squirrel burrows were significantly correlated with East and North UTM coordinate (Figs. 2, 3), % moss, % grass, and % bare ground in the preliminary analysis of the 115 randomly-selected sites by linear regression (Table 8). I further explored the relationship between burrow numbers and % grass by correlations with individual grass species. Of those, Sandberg's bluegrass and six-weeks fescue had a significant positive correlation with the total number of ground squirrel burrows (Table 8). Russian thistle was the only other plant species with a significant correlation and was negatively associated with the total number of burrows (Table 4). A multiple regression using significant variables explained 38% of the variation in number of burrows (Table 4).

The first 2 principal components in analysis of 28 habitat variables sampled at 115

Table 4. Number of burrows of Townsend's ground squirrels on randomly-selected sites in the Snake River Birds of Prey Area relative to presence/absence of military tracks or livestock. Number of burrows was not significantly different among habitat, treatment, and habitat*treatment models (2-way ANOVA, $P > 0.10$).

| | Present | | Absent | |
|---|---|---|---|---|
| | N | Burrows ± S.E. | N | Burrows ± S.E. |
| Military Tracking | | | | |
| Grass Habitats | 20 | 184.0 ± 37.3 | 59 | 170.2 ± 24.6 |
| Shrub Habitats | 6 | 154.2 ± 49.0 | 30 | 159.5 ± 25.9 |
| Livestock | | | | |
| Grass Habitats | 23 | 186.5 ± 48.7 | 56 | 168.4 ± 21.2 |
| Shrub Habitats | 14 | 187.1 ± 46.9 | 22 | 140.5 ± 22.6 |

Table 5. Percent cover of plant species that were significantly different between 89 randomly located sites outside the Orchard Training Area (OTA) and 26 sites within the OTA. Comparison between areas was by Student's t test on arcsine-transformed percentages.

| Species | Outside OTA | | Inside OTA | | t | P |
|---|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | | |
| Big Sagebrush | 6.8 | 1.2 | 2.9 | 1.3 | 1.92 | 0.059 |
| Bur Buttercup | 1.1 | 0.5 | 3.8 | 1.2 | 2.93 | 0.006 |
| Cheatgrass | 16.5 | 2.0 | 4.5 | 2.1 | 4.55 | 0.001 |
| Crested Wheatgrass | 0.6 | 0.2 | 0.01 | 0.02 | 2.85 | 0.005 |
| Peppergrass | 0.3 | 0.01 | 1.1 | 0.4 | 2.15 | 0.04 |
| Russian Thistle | 6.1 | 0.8 | 9.7 | 1.8 | 2.54 | 0.012 |

Table 6. Percent cover of plant species that were significantly different between 71 randomly located sites north of the grazing drift fence (spring and fall grazing) and 44 sites south of the fence (winter grazing). Comparison between areas was by Student's t test on arcsine-transformed percentages.

| Species | North | | South | | t | P |
|---|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | | |
| Bur Buttercup | 2.5 | 0.7 | 0.3 | 0.2 | 3.69 | 0.001 |
| Cheatgrass | 17.8 | 2.2 | 7.3 | 2.3 | 3.77 | 0.001 |
| Peppergrass | 0.8 | 0.2 | 0.03 | 0.02 | 5.67 | 0.001 |
| Sandberg's Bluegrass | 8.8 | 0.8 | 5.6 | 1.0 | 3.35 | 0.001 |
| Six Weeks Fescue | 0.3 | 0.06 | 0.09 | 0.07 | 3.50 | 0.001 |
| Tall Tumblemustard | 4.0 | 0.9 | 0.4 | 0.2 | 5.37 | 0.001 |
| Winterfat | 0.001 | 0.001 | 3.7 | 1.1 | 3.98 | 0.001 |

Table 7. Number of burrows within habitat class for 109 sites sampled in the Integration Study Area in 1991. Six sites were in habitat classes with < 5 observations and were omitted from the analysis. Means with different letters are significantly different ($P < 0.05$) within active, inactive, or total burrow categories.

| | | Number of Burrows | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Active | | Inactive | | Total | |
| Habitat Class | | N | Mean | S.E. | Mean | S.E. | Mean | S.E. |
| 2B1 | Perennial grass | 5 | 242.0$^{A}$ | 88.7 | 112.0$^{A}$ | 69.8 | 354.0$^{A}$ | 135.6 |
| 1A3 | Winterfat | 8 | 183.8$^{AB}$ | 50.4 | 77.5$^{AB}$ | 28.7 | 261.3$^{AB}$ | 73.4 |
| 2C1 | Cheatgrass | 29 | 195.5$^{AB}$ | 36.3 | 47.2$^{AB}$ | 7.6 | 242.8$^{ABC}$ | 40.9 |
| 2A1 | Native Perennial | 5 | 146.0$^{AB}$ | 39.9 | 32.0$^{A}$ | 12.9 | 178.0$^{ABC}$ | 49.9 |
| 1C3 | SAKA/BRTE[a] | 8 | 90.6$^{AB}$ | 28.5 | 39.4$^{AB}$ | 14.9 | 130.0$^{ABC}$ | 35.9 |
| 1A5 | Sagebrush | 5 | 81.0$^{AB}$ | 22.9 | 31.0$^{B}$ | 14.6 | 112.0$^{BC}$ | 26.7 |
| 1B2 | Sagebrush | 17 | 85.0$^{AB}$ | 14.8 | 28.8$^{B}$ | 7.3 | 113.8$^{BC}$ | 20.0 |
| 1C2 | SAKA no BRTE | 32 | 63.4$^{B}$ | 11.2 | 29.7$^{B}$ | 5.4 | 93.1$^{C}$ | 15.1 |

[a] SAKA = Russian thistle; BRTE = cheatgrass

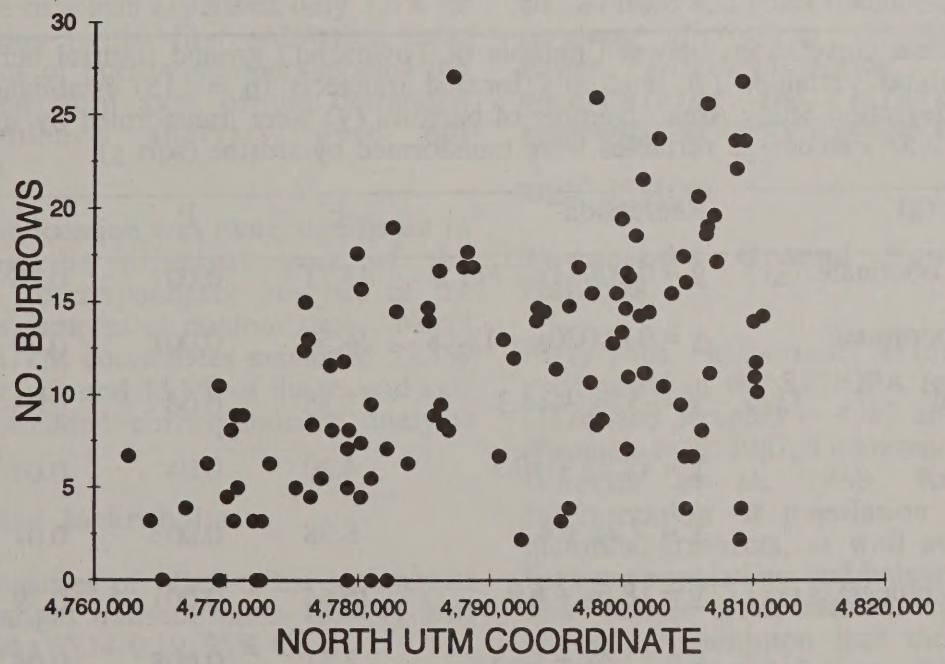


Fig. 2. Relationship between number of burrows/ha and North UTM coordinate. Number of burrows/ha is the square root transformation.

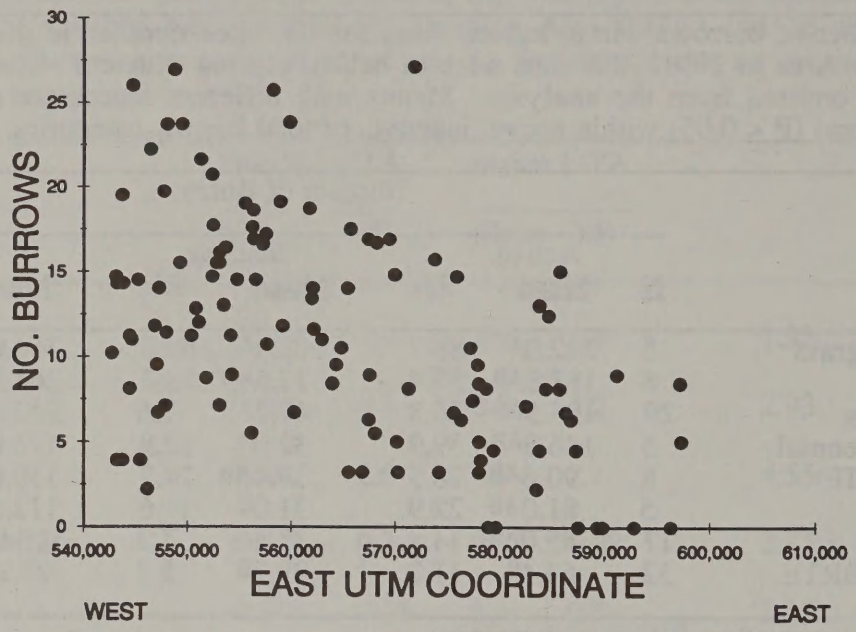


Fig. 3. Relationship between number of burrows/ha and East UTM coordinate. Number of burrows/ha is the square root transformation.

Table 8. Linear correlations between number of Townsend's ground squirrel burrows and habitat variables for randomly located transects ($n$ = 115) established in the Integration Study Area. Number of burrows ($y$) were transformed by square root + 0.5. Percentage variables were transformed by arcsine (sqrt $x$).

| Characteristic ($x$) | Regression | F | P | $r^2$ |
|---|---|---|---|---|
| North UTM Coordinate ($x_1$) | $y = 0.00021x - 711.2$ | 43.71 | 0.001 | 0.28 |
| East UTM Coordinate | $y = 0.00020x + 127.8$ | 34.51 | 0.001 | 0.23 |
| % Bare ground ($x_2$) | $y = -5.9x + 14.3$ | 3.35 | 0.06 | 0.03 |
| % Moss | $y = 12.3x + 10.2$ | 4.20 | 0.04 | 0.04 |
| % Grass | $y = 7.2x + 8.1$ | 8.98 | 0.003 | 0.07 |
| % Sandberg's bluegrass ($x_3$) | $y = 18.6x + 6.9$ | 26.64 | 0.001 | 0.19 |
| % Fescue | $y = 41.4x + 15.3$ | 7.31 | 0.008 | 0.06 |
| % Russian thistle | $y = -7.93x + 13.0$ | 5.27 | 0.02 | 0.04 |
| Mult. Reg. | $y = 0.00028x_1 + 10.0x_2 + 11.1x_3 - 1320.12$ | 2.36 | 0.0001 | 0.38 |

randomly-located sites accounted for 12.6 and 10.2% of the total variation; succeeding axes contributed < 8% of the total variation explained (Table 9). Factor loadings for the first axis were highest for % bare ground (Eigenvector = -0.449), % moss (Eigenvector = 0.407), and % Russian thistle (Eigenvector = -0.407). Regression of burrow numbers against principal component axes was significant only for axis 1 (Table 9). North and East UTM coordinates were more significant in explaining the variation in the habitat variables (Table 9). The North UTM coordinate explained 51.8% of the first and 3.0% of the second axis. The East UTM coordinate explained 8.8% of axis 1 and 24.3% of axis 2.

The first axis of the detrended correspondence explained 14.3% of the variation in 26 habitat variables (excluding % bare ground and % moss) at 115 randomly located sites (Fig. 4); axes 2 and 3 contributed an additional 7.6 and 6.7% (Table 10). Regression of total burrow numbers against the first axis explained only 7.4% of the variation in the first ordination axis. Regressions of burrow numbers against the second and third axes of the detrended correspondence analysis were not significant.

Geographic location was more significant in explaining the principal axes of the detrended correspondence analysis of the vegetation samples at random sites. North and East UTM coordinates explained 55.1% of the first axis and 33.8% of the second axis in the detrended correspondence analysis (Table 10).

### Black-tailed Jackrabbits

Winter densities of black-tailed jackrabbits along spotlight transect routes (394.41 km) were 0.16/ha (0.14-0.19, 95% C.I.).

Sightings on new and historical transects were similar in mean location ($\underline{z}$ = 1.37, $\underline{P}$ = 0.17) and distribution of distances ($\underline{D}$ = 0.076, $\underline{P}$ = 0.51). Spring densities were lower along the newly established transects (136.6 km) (0.15; 0.12-0.18, 95% C.I.) compared to historical transects (467.1 km) (0.22; 0.19-0.25, 95% C.I.) ($\underline{z}$ = -3.17, $\underline{P}$ = 0.002). I did not combine results from new and historical rabbit transects (Fig. 5).

Density estimates for both new and historical transects were lower than for spring 1990 (Fig. 5). In 1991, jackrabbits were in the second year of a cyclic decline after a peak in 1989.

Densities of jackrabbits were higher ($\underline{z}$ test, $\underline{P} < 0.05$) on transects conducted inside the OTA when compared to transects outside the OTA and north of the Snake River for either winter and spring surveys (Table 11). Densities of jackrabbits were higher on transects that were south of the grazing drift fence for both winter or spring surveys (Table 12).

We also observed 20 Nuttall's cottontail rabbits, 2 pygmy rabbits, 862 kangaroo rats, and 24 mice and voles (including *Lemmiscus curtatus*, *Microtus* sp., *Onychomys leucogaster*, *Perognathus parvus*, *Peromyscus maniculatus*, and *Reithrodontomys megalotis*) on spring spotlight transects.

## DISCUSSION

### Townsend's Ground Squirrels and Habitats

Fifty-four historical transects were established in the SRBOPA (excluding the OTA) and sampled in 1982 and 1986-1990 (Quinney et al. 1987, Timmerman et al. 1988, Wheeler et al. 1989, Knick 1990). Interpretation of population trends from historical transects, as well as correlations between populations and habitat qualities on new sample sites, remains linked to the untested assumption that the number of burrows and populations are correlated. Study 4 of the BLM/IDARNG Research Project is investigating the relationship between population and burrow density (Van Horne et al., this volume).

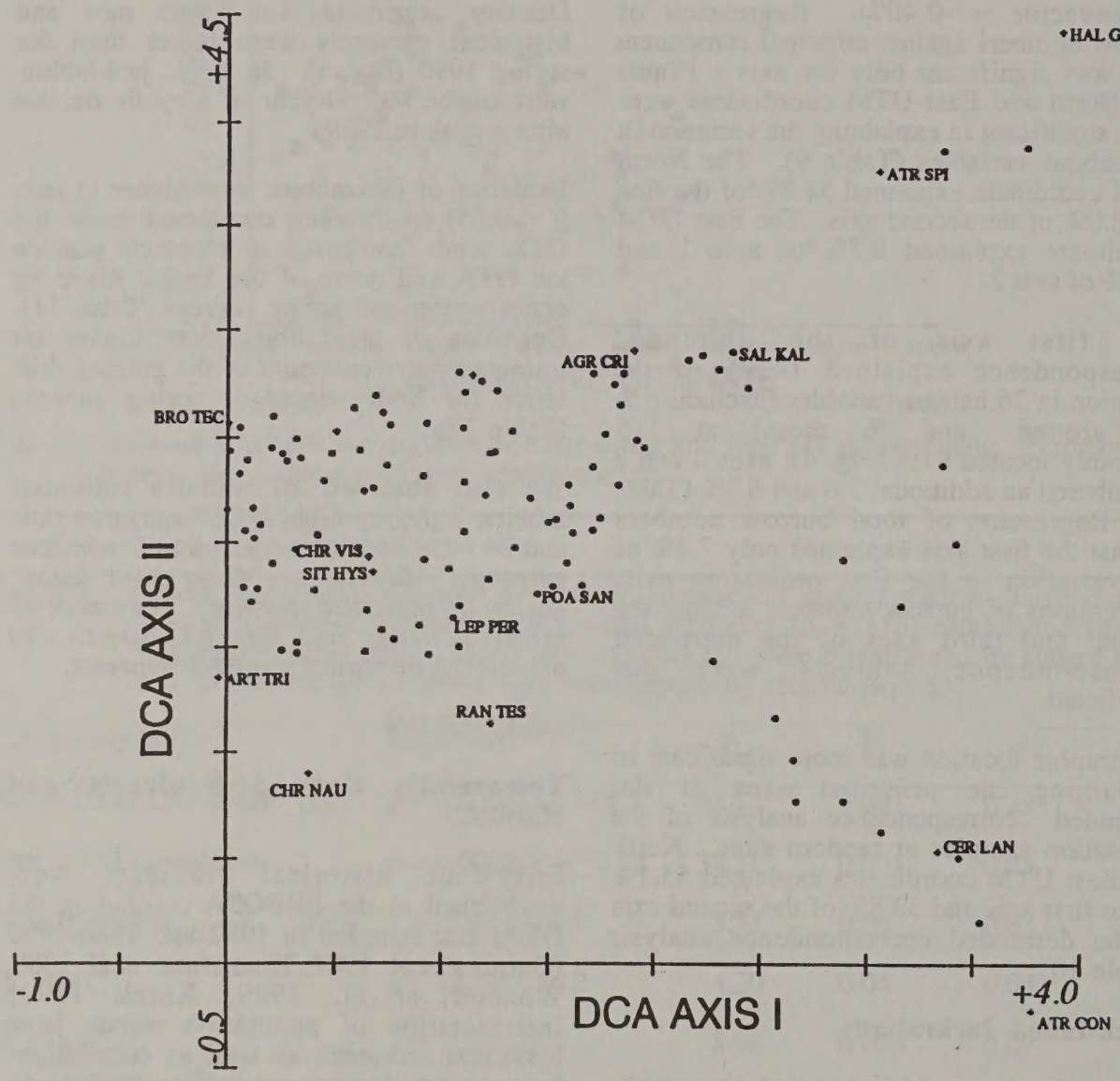


Fig. 4. Joint plot of vegetation and sampling sites for the ordination by detrended correspondence analysis.

Table 9. Principal components analysis of 26 habitat variables sampled at 115 randomly located sites in the ISA during 1991. Analyses were performed on arcsine-transformed percentage data. Regression of burrow counts of Townsend's ground squirrels (TGS) and UTM coordinates are presented for each component axis with a significant response.

| | Correlation Matrix | | | |
|---|---|---|---|---|
| | PRIN1 | PRIN2 | PRIN3 | PRIN4 |
| Eigenvalue | 3.53 | 2.87 | 2.20 | 1.65 |
| Tot. Var. (%) | 12.63 | 10.25 | 7.84 | 5.90 |
| Cum. Var. (%) | 12.63 | 22.88 | 30.72 | 36.62 |
| TGS Regression | | | | |
| Variation Explained ($r^2$) | 7.0 | | | |
| $E_{1,113}$ = | 9.63 | | | |
| P = | 0.002 | | | |
| North UTM Regression | | | | |
| Variation Explained ($r^2$) | 51.8 | 2.6 | | |
| $E_{1,113}$ = | 121.19 | 4.07 | | |
| P = | 0.0001 | 0.046 | | |
| EAST UTM Regression | | | | |
| Variation Explained ($r^2$) | 8.8 | 24.3 | | |
| $E_{1,113}$ = | 12.01 | 37.60 | | |
| P = | 0.0008 | 0.0001 | | |

Table 10. Detrended correspondence analysis of vegetation samples from randomly located sites in the ISA during 1991. The analysis included 26 vegetation species and 115 sample sites. Cumulative percent variation explained and correlations with each axis of the vegetation model are presented for full and reduced models of burrow counts of Townsend's ground squirrels (TGS) and UTM coordinates.

| | Detrended Correspondence Axes | | | |
|---|---|---|---|---|
| Model | 1 | 2 | 3 | 4 |
| Eigenvalues | 0.76 | 0.40 | 0.35 | 0.21 |
| Length of gradient | 3.74 | 3.88 | 2.73 | 2.46 |
| Cum. Percent Variation | 14.3 | 21.9 | 28.6 | 32.4 |
| TGS Regression | | | | |
| Cum. Percent Variation | 7.4 | 0.0 | 0.0 | 0.0 |
| Correlation | 0.095 | 0.052 | 0.060 | 0.156 |
| East/North UTM Regression | | | | |
| Cum. Percent Variation | 42.5 | 52.1 | 0.0 | 0.0 |
| Correlation | 0.623 | 0.343 | 0.407 | 0.250 |
| TGS/East/North UTM Regression | | | | |
| Cum. Percent Variation | 80.2 | 0.0 | 0.0 | 0.0 |
| Correlation | 0.575 | 0.212 | 0.163 | 0.170 |

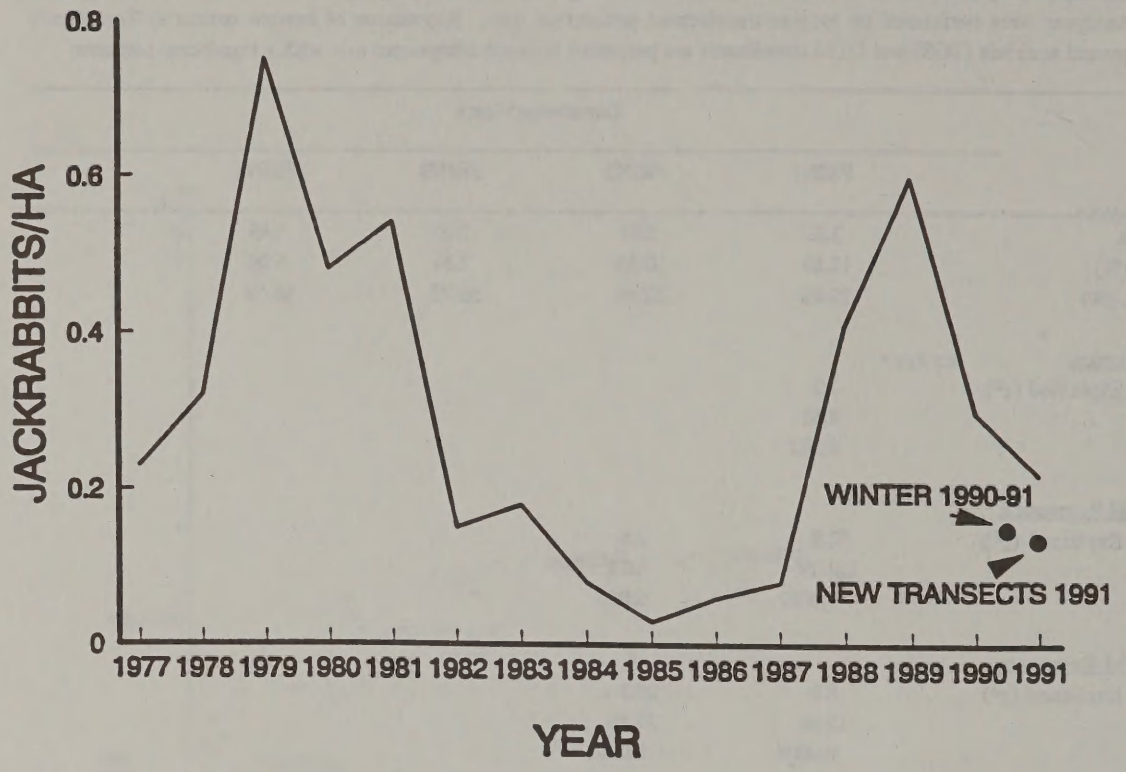


Fig. 5. Densities of black-tailed jackrabbits in the Snake River Birds of Prey Area from 1977-1991.

Table 11. Number of jackrabbits and estimates of densities for transects within the Orchard Training Area (military training) and Integration Study Area (no military). Densities were higher for transects on the Orchard Training Area compared to the Integration Study Area during both winter ($\underline{z} = 4.56$, $\underline{P} < 0.01$) and spring ($\underline{z} = 3.94$, $\underline{P} < 0.01$) surveys.

| Area | N | No./Ha | S.E. | C.V. | 95% C.I. |
|---|---|---|---|---|---|
| Winter 1990-91 | | | | | |
| Orchard Training Area | 61 | 0.63 | 18.3 | 0.115 | 0.44 - 0.90 |
| Integration Study Area | 117 | 0.10 | 10.6 | 0.011 | 0.08 - 0.13 |
| Spring 1991 | | | | | |
| Orchard Training Area | 109 | 0.25 | 8.0 | 0.020 | 0.21 - 0.29 |
| Integration Study Area | 403 | 0.16 | 6.7 | 0.106 | 0.14 - 0.18 |

Table 12. Number of jackrabbits and estimates of densities for transects north (spring and fall grazing) and south (winter grazing) of the drift fence. Estimates of density were higher on the south transects for both winter ($z = 5.17$, $P < 0.001$) and spring ($z = 2.55$, $P = 0.02$) surveys. All transects were north of the Snake River.

| Area | N | No./Ha | S.E. | C.V. | 95% C.I. |
|---|---|---|---|---|---|
| Winter 1990-91 | | | | | |
| North of Drift Fence | 39 | 0.06 | 0.012 | 20.7 | 0.04 - 0.09 |
| South of Drift Fence | 139 | 0.17 | 0.017 | 10.4 | 0.14 - 0.20 |
| Spring 1991 | | | | | |
| North of Drift Fence | 180 | 0.25 | 0.025 | 9.9 | 0.21 - 0.31 |
| South of Drift Fence | 429 | 0.18 | 0.011 | 5.9 | 0.16 - 0.20 |

The number of active and total burrows counted on historical sites in 1991 was the highest since 1987 and may represent increased populations of ground squirrels. The higher number of burrows counted on historical transects relative to 1990 may be due to our interpretation of active burrows (Knick 1990). We were more conservative in classifying active burrows in 1990 than in 1991. From tests of observer bias, classification of active/inactive status was the largest source of errors on burrow count transects (Knick 1990). Classification of active status may become more difficult after ground squirrels immerge. Therefore, we will begin our hole counts in May during 1992 minimize this potential bias.

The objective of the analyses of burrow counts and habitat variables was to extract key habitat characters that predicted number of ground squirrel burrows. For this, I used a variety of statistical techniques. The first approach was to relate the number of burrows directly to single or multiple sets of variables. The second approach was to summarize the variation in the habitats and then determine if the number of burrows was related to that variation. Neither approach produced strong relationships. The most variation in the number of burrows explained by any single variable was 28% (North UTM coordinate) and 38% for any suite of variables or ordination. The low variation explained by the analyses suggests that the abundance of ground squirrel populations also is largely influenced by other factors. An emerging pattern from the 1991 analysis of random sites is that abundance of burrows has both a geographic and vegetative component. The number of burrows decreased from northwest to southeast in the ISA. The number of burrows also was positively correlated with Sandberg's bluegrass and six-weeks fescue. Both species were important foods of Townsend's ground squirrels (Yensen 1989).

The negative correlation between burrow numbers and Russian thistle has strong implications for habitat alterations in the SRBOPA. Disturbances, such as wildfires, greenstripping, overgrazing, or soil erosion, that result in takeover by Russian thistle (Yensen 1980) may reduce resident populations of Townsend's ground squirrels.

Vegetation also had a strong geographic component and confounded the interpretation of burrow counts relative to habitats. The correlation between burrow numbers and plant species may be an artifact of a vegetation gradient rather than a direct causal relationship. Similarly, the differences in percent cover of vegetation relative to the grazing drift fence or OTA more likely represent a geographical distribution of the vegetation rather than

differences in grazing regime or military tracking.

**Black-tailed Jackrabbits**

Jackrabbits have been censused in the Snake River Birds of Prey Area by night spotlight counts using line transect methods since 1977 (Wolfe et al. 1977). Black-tailed jackrabbits are cyclic with approximate 7-12 year intervals between peaks (Johnson and Peek 1984). In the Snake River Birds of Prey Area, densities peaked in 1979 and again in 1989. Estimates of jackrabbit densities decreased in 1991 from 1989 and 1990 levels and suggest that densities, although still high, are now in the decline phase of the cycle.

The differences in estimates of jackrabbit densities relative to the grazing drift fence or OTA are likely due to vegetation gradients rather than difference caused by grazing system or military tracking. Regional comparisons should be viewed with caution because no attempt was made to proportionally sample habitats between regions.

PLANS FOR NEXT YEAR

**Townsend's Ground Squirrels and Habitats**

The sampling effort for ground squirrels and habitats will be expanded to 450 sites randomly selected throughout the Integration Study Area and the OTA. We will continue to conduct burrow counts on the historical transects and a random subsample of the randomly-selected sites from 1991 to define yearly variation in populations and habitats (Fretwell 1972, Southwood 1977, Hanski 1985). Spatial distribution of ground squirrel burrow counts and habitat variables will be modeled by contouring functions on the GIS.

Resiliency of Townsend's ground squirrel populations and habitats to military tracking will also be assessed by manipulated tracking within a random block design entirely within a habitat type. Counts of ground squirrel burrows and vegetation sampling will be conducted in each year during pre/post tracking periods to estimate influence of military tracking.

**Black-tailed Jackrabbits**

We will continue spotlight counts for estimates of spring densities on historical transects. We will sample each transect twice and add additional routes to increase the area and treatments sampled. We will survey historical and new transects throughout the SRBOPA by spotlight methods (Smith and Nydegger 1985) during December to determine winter jackrabbit densities and distribution. In addition, we will attempt to relate habitats to jackrabbit densities to aid in regional comparisons of estimates.

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Appendix 1. Common and scientific names, and 4-letter codes for plant species listed in tables.

| Common Name | Scientific Name | Code |
|---|---|---|
| Big Sagebrush | *Artemisia tridentata* | ARTR |
| Bottlebrush Squirreltail | *Sitanion hystrix* | SIHY |
| Bur Buttercup | *Ranunculus testiculatus* | RATE |
| Bud Sage | *Artemisia spinescens* | ARSP |
| Cheatgrass | *Bromus tectorum* | BRTE |
| Crested Wheatgrass | *Agropyron cristatum* | AGCR |
| Gray Rabbitbrush | *Chrysothamnus viscidiflorus* | CHVI |
| Greasewood | *Sarcobatus vermiculatus* | SAVE |
| Green Rabbitrush | *Chrysothamnus nauseosus* | CHNA |
| Halogeton | *Halogeton glomeratus* | HAGL |
| Nuttall's Saltbush | *Atriplex nuttallii* | ATNU |
| Peppergrass | *Lepidium perfoliatum* | LEPE |
| Russian Thistle | *Salsola iberica* | SAKA |
| Sandberg's bluegrass | *Poa secunda* | POSA |
| Shadscale | *Atriplex confertifolia* | ATCO |
| Six Weeks Fescue | *Festuca octoflora* | FEOC |
| Tall Tumblemustard | *Sisymbrium altissimum* | SIAL |
| Tansymustard | *Descurainia pinnata* | DEPI |
| Winterfat | *Ceratoides lanata* | CELA |

# Use of Satellite Imagery to Delineate Habitats in the Snake River Birds of Prey Area

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*Annual Summary*

*Twenty-six habitat classes were described from previous vegetation transects that were surveyed in the Snake River Birds of Prey Area (SRBOPA). These habitats were then used to translate spectral qualities of a May 1989 satellite image into a map of habitats in the SRBOPA.*

## OBJECTIVES

1. To develop a habitat classification scheme for the SRBOPA.
2. To use satellite imagery to delineate habitats in the SRBOPA.

## INTRODUCTION

An accurate map of vegetation is critical both to immediate concerns of the Bureau of Land Management/Idaho Army National Guard Research Project (BLM/IDARNG) and to long-term goals of global climate change research (Knick this volume). The success of Studies 1, 2, 3, and 5 of the BLM/IDARNG Research Project depends on spatial analyses of vegetative patterns to provide information on patterns of raptor foraging or prey distributions. An accurate habitat map of the SRBOPA also can provide baseline information to assess the influence of a changing global climate on habitats (Burke and Kiester 1990, Schlesinger et al. 1990). Quantitative evaluation of vegetation patterns in the SRBOPA may provide data on shifting species ranges or community reorganization that may be attributable to environmental changes (Munn 1988, Davis 1989, Peters 1989, Graham and Grimm 1990).

We are using satellite imagery and geographical information systems (GIS) as a tool (Burke et al. 1990, Podolsky and Morehouse 1990) to determine vegetation in the SRBOPA.

## METHODS

Development of the GIS map of current vegetation on the SRBOPA involved an iterative procedure (Fig. 1). We first

classified habitats from existing vegetation data and then correlated habitat classification with spectral quality of pixels at geographically precise locations in the image. Global changes were then made to translate spectral quality to habitat class for the entire image. New data from subsequent year's field results will be used to assess the accuracy of the image in reflecting our classification scheme and will be followed by subsequent reclassification(s). The process will be repeated until an acceptable level of accuracy ($\geq$ 90%) is attained in all vegetation categories.

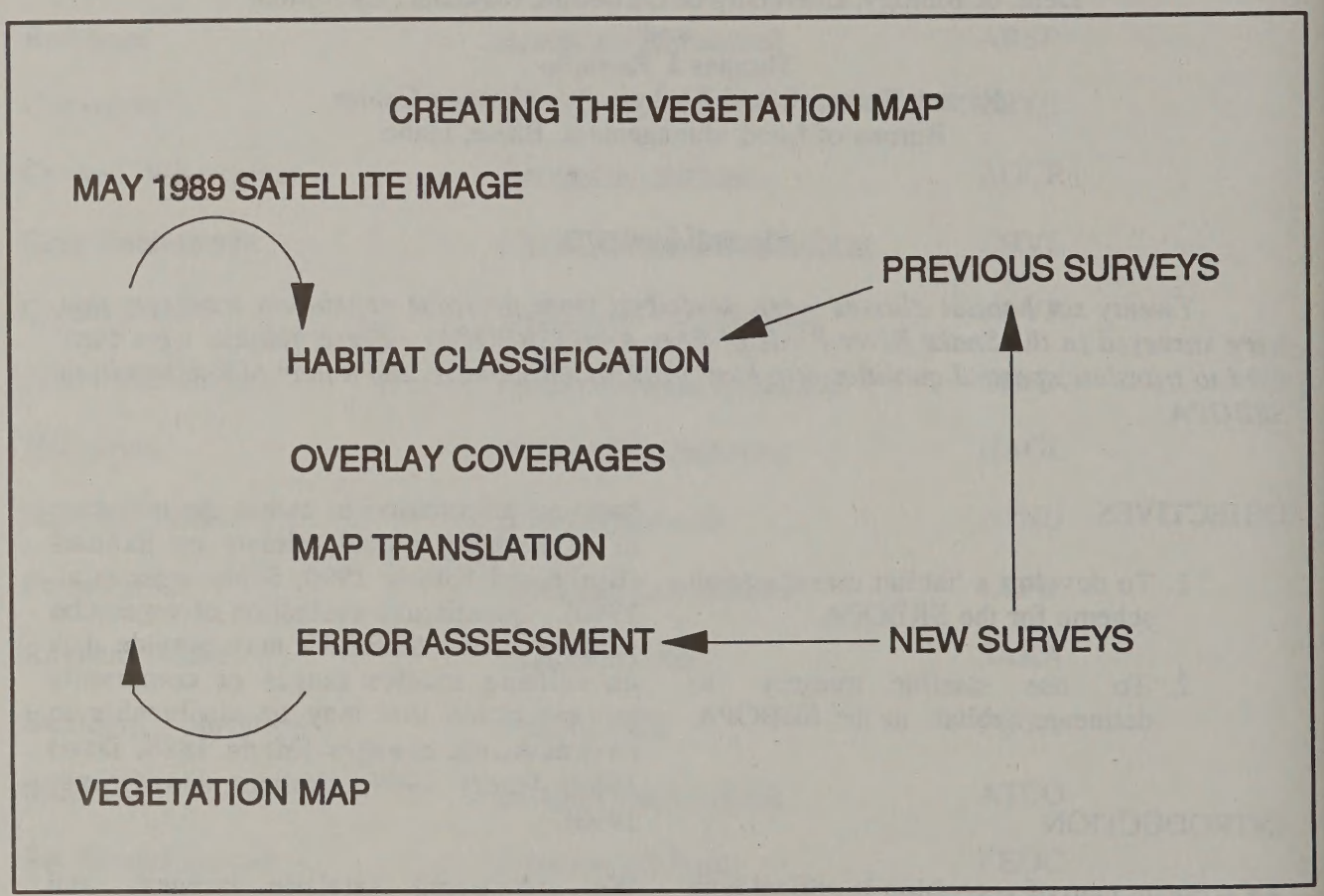


Fig. 1. Flow chart for the iterative process of developing the vegetation map for the Snake River Birds of Prey Area from satellite imagery.

## Satellite Imagery

The current map layer in the GIS at the Raptor Research and Technical Assistance Center is a Thematic Mapper satellite image taken in May 1989. The image was originally processed into 43 categories that represented variation in spectral qualities. An initial attempt to classify this image into 14 vegetation categories was < 70% accurate.

The May 1989 image for the SRBOPA was subsequently reprocessed into 55 spectral categories that incorporated an additional spectral band. The processed satellite image depicted polygons composed of 30-$m^2$ pixels of a contiguous spectral class. This image does not describe vegetation classes and was the starting point for creating the vegetation map. The original 55 spectral categories included water, urban areas, and agriculture.

## Existing Vegetation Data

All existing vegetation data since 1987, both quantitative and qualitative, were used to identify appropriate vegetation (= habitat) categories or classes. We did not use information collected prior to 1987 because of potential vegetation changes that could obscure current classifications.

## Habitat Classification

We employed a combination of statistical and empirical approaches to deriving vegetation classes from the existing vegetation data. First, we subjected 379 existing samples of vegetation data to a cluster analysis (PROC FASTCLUS, SAS Statistical Institute 1988), specifying 14 initial clusters, to identify natural groups of vegetation. Fourteen groups were selected as an appropriate number of initial clusters based on inspection of the data and our estimation of the number of different vegetation types. Distinctness of the resulting classes was confirmed by performing a discriminant analysis of the 379 samples (PROC DISCRIM, SAS Statistical Institute 1988), using cluster membership as the classification variable and species coverage values as predictor variables. Finally, we added habitat types not represented in the original samples, but which our field experience indicated were present.

## Translation of Satellite Imagery into Habitat Categories

Only sites that were georeferenced by a Global Positioning System (GPS) were used to correlate vegetation data with spectral quality of pixels. The geographic accuracy of sites surveyed by a GPS was estimated to be $\pm$ 5-25 m.

Vegetation at sites in the data set used for image classification was sampled by line intercept along a 100-m transect ($\underline{N}$ = 133) (Quinney 1990) or point frame techniques along a 400-m transect ($\underline{N}$ = 167) (Knick 1990). Habitat class was determined for each site using a discriminant function analysis (PROC DISCRIM, SAS Statistical Institute 1988) with the original habitat surveys defining the training set.

Buffered circles of 100-m radius were drawn around the starting point of the sites sampled by line intercept. A 50-m buffer was drawn around each 400-m transect line from the starting point in the direction of the transect angle.

The coverage of vegetation surveys was then overlayed with the coverage of spectral class. Relationship between spectral class and habitat was determined by intersections of both starting point for the transect and the buffered region with the underlying pixels in the spectral class coverage.

### Assessment of Accuracy

Accuracy of the habitat classification in the satellite image was tested by constructing an error matrix of results from 70 vegetation surveys that were not used in the original image translation.

These surveys were randomly-located sites sampled by Study 5 in 1990 and 1991 (Knick 1990, 1991 this volume).

## RESULTS

### Habitat Classification

We determined an initial habitat classification (Tables 1 and 2) with data from the following sources: (1) 198 vegetation surveys in the Orchard Training Area collected by the Idaho Army National Guard as part of the Land Condition Trend Analysis (Quinney 1990); (2) 44 random locations that were used for ground verification of the satellite image (Raptor Research and Technical Assistance Center, unpubl. data); (3) 47 transects from the pilot study of Study 5 of the BLM/IDARNG Research Project (Knick 1990); (4) 61 vegetation surveys on traditional ground squirrel transects (Wheeler et al. 1989); and (5) 16 transects from a study to assess burns in shadscale habitats (Groves and Steenhof 1988).

### Translation of Satellite Imagery in Habitat Categories

Number of pixels sampled in each spectral class for the coverage of buffered points and lines ranged from 0 (spectral class 4) to 929 (spectral class 49). Each spectral class represented from 1-14 habitat classes (Table 3). Therefore, habitat class was determined for each spectral class based on the probability of a habitat's representation in the spectral class.

We refined the probabilities for some ambiguous spectral classes by regional subsampling. A northwestern quadrant of the SRBOPA was determined from the southeastern corner of the Big Foot Butte quadrangle. Fewer pixels were sampled (7,681 pixels in the NW quadrant vs 12,765 pixels for the full coverage) but variation from outlying vegetation was removed.

### Assessment of Accuracy

Twenty-two randomly-located transects in the northwest portion of the SRBOPA were used to assess the accuracy of the vegetation map for Initial Point, Big Foot Butte, Coyote Butte, and Christmas Mountain quadrangles (Table 4). In addition, 70 transects that represented the Integration Study Area of the SRBOPA were used to assess the accuracy of global changes for the entire vegetation map (Table 5).

The image was the most accurate in classifying disturbed habitats (Classes IC1, IC2, IC3, and IIC1); 93.7% of all pixels (5,930 of 6,327) described as disturbed in the field transects were classed as disturbed in the satellite image (Table 5). However, the image incorrectly classed 48.5% (4,458 of 9,190) of the pixels in shrub habitats (Classes IA2-5 and IB1-2) and 56.9% (1,714 of 3,012) of the pixels in grass habitats (classes IIA1, IIB1, and IIC1) as disturbed (Table 5). The largest errors were in distinguishing between disturbed habitats containing Russian thistle (*Salsola iberica*) and shrub habitats.

Within specific habitat classes, medium density big sagebrush (*Artemisia tridentata*) (class IB2) was the most accurate and was correctly classified in 70.9% (1,502 of 2,118) of the pixels in the image. Collectively, medium and high density sagebrush (classes IA5 and IB2) were correctly classified in 62.6% (2,643 of 4,223) of the pixels in the image.

Table 1. Habitat classes determined from vegetation surveys on the Snake River Birds of Prey Area 1987-1990. Vegetation composition for each class is presented in Table 2.

I. Shrubland
- A. Low disturbance
  1. shadscale + perennial grasses, native forbs
  2. shadscale + winterfat
  3. winterfat
  4. sagebrush + winterfat
  5. sagebrush (high density) + perennial grasses, native forbs
  6. greasewood
  7. saltbush
  8. gray rabbitbrush
- B. High disturbance
  1. shadscale + BRTE + SAKA
  2. sagebrush (medium density) + BRTE, perennial grasses
  3. green rabbitbrush
  4. reseeding - shrubs
- C. Extreme disturbance
  1. sagebrush (low density) + SAKA
  2. SAKA
  3. SAKA + BRTE

II. Grassland
- A. Low disturbance
  1. native perennial grasses
- B. High disturbance
  1. perennial grasses + exotic annual (esp. SAKA)
  2. reseeding - bunchgrass
- C. Extreme disturbance
  1. BRTE (+ mustards)
  2. bare ground (including roads)

III. Artificial
- A. High disturbance
  1. agricultural (including fallow)
- B. Extreme disturbance
  1. "urban" (buildings, constructions, and their surroundings)

IV. Other
- A. Low disturbance
  1. riparian
  2. water
  3. rock

BRTE = cheatgrass, SAKA = Russian thistle.

Table 2. Approximate plant species composition and percent cover of vegetation/habitat classes. Estimates of percent cover were based on averages of 10-65 samples per class and 379 total samples. See Table 1 for class names. Common and scientific names are given in Appendix A.

| | Habitat Class[a] | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | IA1 | IA2 | IA3 | IA4 | IA5 | IA6 | IA7 | IA8 | IB1 | IB2 | IB3 | IC1 | IC2 | IIC3 | IIA1 | IIB1 | IIC1 |
| Shrubs | | | | | | | | | | | | | | | | | |
| ATCO | 14 | 20 | 1 | | | | 1 | | 17 | | | | | | | | |
| CELA | 2 | 2 | 28 | 4 | | | | | | | | | 1 | | | | |
| ARSP | 6 | 1 | 2 | | | | | | | | | | | | | | |
| ARTR | 3 | | 1 | 28 | 29 | | 4 | | 1 | 13 | | 2 | | | | | |
| SAVE | | | | | | 12 | | | | | | | | | | | |
| CHNA | | | | | | | | 8 | | | | | | | | | |
| ATNU | | | | | | | 17 | | | 2 | | | | | | | |
| CHVI | | | | | | | | | | | 8 | | | | | | |
| Perennial Grasses | | | | | | | | | | | | | | | | | |
| POSA | 17 | | 19 | 23 | 17 | | 13 | | | 2 | 27 | 21 | | 9 | 27 | 32 | |
| SIHY | 11 | 3 | 1 | 3 | 5 | 6 | | | | | | 4 | | 3 | 4 | 6 | 3 |
| FEOC | | | | | 4 | | | | | | | | | | 1 | | |
| AGCR | | | | | | | | | | 2 | | | | 1 | | | |
| Exotic Annuals | | | | | | | | | | | | | | | | | |
| BRTE | | 18 | | | | | | | 6 | 18 | 21 | 25 | | 25 | 6 | 3 | 30 |
| SAKA | 8 | | | | | 24 | 5 | 17 | 19 | | 3 | 12 | 34 | 29 | 1 | 17 | |
| Mustards | | | | | | | | | | | | | | | | | |
| DEPI | | | | | | | | | 1 | | | | 2 | | | | 9 |
| LEPE | | | | | | | | | | | 19 | 4 | 2 | 1 | 22 | 5 | 3 |
| SIAL | | | | | | | | | | | | 1 | 1 | 1 | 5 | 5 | 6 |
| Other Forbs | | | | | | | | | | | | | | | | | |
| RATE | | | | | 4 | | | | | | 3 | 9 | | | 7 | | 5 |
| HAGL | | | | | | | | | 4 | 4 | | | | | | | |

[a] Classes IB4, IIB2, IIC2, III, and IV are self-evident and were not sampled.

Table 3. Number of pixels sampled in the May 1989 satellite image by spectral class and habitat class for the Snake River Birds of Prey Area. Fifty-five spectral classes were determined from cluster analysis of 4 spectral bands from the original unsupervised Thematic Mapper satellite image. Habitat classes are described in Table 2. Habitat samples represent the buffered region around the 400-m and 100-m vegetation transects.

| Spectral Class | Habitat Class | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1A1 | 1A2 | 1A3 | 1A4 | 1A5 | 1A6 | 1A7 | 1A8 | 1B1 | 1B2 | 1B3 | 1C1 | 1C2 | 1C3 | 2A1 | 2B1 | 2B2 | 2C1 | 2C2 | Total |
| 0 | | | | | | | | | | | | | 1 | | | | | | | 6 |
| 1 | | | 1 | | 59 | | | | | | | | 3 | 7 | 5 | 15 | | 2 | | 92 |
| 2 | | | | | <1 | | | | | 5 | | | | 2 | | 3 | | 1 | | 11 |
| 3 | | | 2 | | 7 | | | | | | | | 8 | 1 | 8 | 4 | | | | 30 |
| 5 | | | | | | | | | | 46 | | | | | | | | 2 | | 48 |
| 6 | | | | | | | | | | <1 | | | | 6 | | | | | | 6 |
| 7 | | | 3 | | 4 | | | | | | | | | <1 | | 3 | | 4 | | 14 |
| 8 | | | | | | | | | | | | | | 4 | | | | | | 4 |
| 9 | | | | | | | | | | 12 | | | | 26 | 5 | | | 4 | | 47 |
| 10 | | | | | 82 | | | | | 99 | 8 | | | | 1 | | | 2 | | 191 |
| 11 | | | | | | | | | | | | | | 56 | | | | 24 | | 80 |
| 12 | | | | | | | | | | 14 | <1 | | | 5 | 6 | | | 7 | | 32 |
| 13 | | | 1 | | 1 | | | | | 6 | 9 | | | 46 | 3 | 18 | | 2 | | 89 |
| 14 | | | | | 58 | | | | | 191 | | | | 6 | 23 | | | 15 | | 293 |
| 15 | | | | | | | | | | | | | | 12 | | | | 29 | | 42 |
| 16 | | | 14 | | 11 | | | | | <1 | | | | 1 | 13 | | | 2 | | 42 |
| 17 | | | 4 | | 40 | | | | | 55 | 1 | | | 37 | 37 | 5 | | 83 | | 262 |
| 18 | | | 2 | | <1 | | | | | | | | 8 | | | | | 10 | | 10 |
| 19 | | | 8 | | 219 | | | | | 69 | | | 5 | | 40 | | | 33 | | 374 |
| 20 | | | 14 | | 18 | | | | | 22 | | | 20 | 60 | 33 | 17 | | 20 | | 205 |
| 21 | | | | | 2 | | | | | 8 | | 45 | <1 | 1 | 123 | 94 | 56 | 80 | | 411 |
| 22 | | | | | 129 | | | | | 69 | | 32 | | 14 | | 109 | 11 | 92 | | 454 |
| 23 | | | | | | | | | | <1 | | | | 6 | | | 6 | 15 | | 28 |
| 24 | | | 13 | <1 | 2 | | | | | 20 | | | | 65 | 21 | 40 | 34 | 31 | | 226 |
| 25 | | | | | 47 | | | | | | 14 | | | 4 | 36 | 109 | 24 | 85 | | 319 |
| 26 | | | 32 | | 129 | | | | | 41 | | | 29 | 38 | 24 | 70 | 34 | 46 | | 442 |
| 27 | | | 10 | <1 | 11 | | | | | 3 | 1 | | | 23 | 133 | 105 | 74 | 181 | | 541 |

Table 3. Continued.

| Spectral Class | Habitat Class | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1A1 | 1A2 | 1A3 | 1A4 | 1A5 | 1A6 | 1A7 | 1A8 | 1B1 | 1B2 | 1B3 | 1C1 | 1C2 | 1C3 | 2A1 | 2B1 | 2B2 | 2C1 | 2C2 | Total |
| 28 | | | 1 | | | | | | 1 | 3 | | | 26 | 12 | | | | | | 42 |
| 29 | | | 2 | | 116 | | | | | 6 | 9 | 3 | 13 | 5 | 91 | 81 | | 82 | | 408 |
| 30 | | | <1 | | | | | | | <1 | | 5 | | 31 | 1 | 59 | | 24 | | 120 |
| 31 | | | 68 | <1 | 5 | | | | | 20 | | 28 | 65 | 25 | 48 | 30 | | 22 | | 311 |
| 32 | | | 21 | | 3 | | | | | | | 15 | 2 | 63 | 15 | 69 | | 70 | | 258 |
| 33 | | | | | | | | | | | | | 2 | | | | | | | 2 |
| 34 | | | 28 | 2 | 41 | | | | 11 | 17 | | 46 | 76 | 34 | 82 | 58 | | 109 | | 503 |
| 35 | | | 9 | | 2 | | | | | | | 4 | 33 | 7 | 22 | 15 | | 33 | | 126 |
| 36 | | | 41 | 4 | 16 | | | | | 10 | | 6 | 5 | 95 | 76 | 138 | | 70 | | 461 |
| 37 | 29 | 5 | 21 | | 23 | | | | 30 | 40 | 3 | 2 | 52 | 88 | 106 | 96 | | 79 | | 584 |
| 38 | 29 | 31 | 67 | | 11 | | | | 111 | | | <1 | 158 | | | | | 43 | | 455 |
| 39 | | | | | | | | | | | | | 12 | | | | | <1 | | 13 |
| 40 | | | 22 | | 8 | | | | | 6 | | 62 | 96 | 35 | 6 | 21 | | 102 | | 358 |
| 41 | | 17 | 241 | 19 | 11 | | | | 25 | 3 | | 73 | 158 | 56 | 7 | 132 | | 129 | | 871 |
| 42 | | | | | | | | | | | | | | | | 2 | | 1 | | 2 |
| 43 | | 1 | 37 | 2 | 95 | | | | 4 | | | 97 | 111 | 74 | 157 | 264 | | 13 | | 856 |
| 44 | | | 2 | | | | | | 13 | 4 | | 2 | 83 | 13 | | 8 | | 92 | | 218 |
| 45 | 10 | 119 | 283 | 7 | | | | | 90 | | | 20 | 185 | 30 | 5 | 31 | | 95 | | 910 |
| 46 | | | 3 | | | | | | | | | 1 | | | | | | <1 | | 4 |
| 47 | | | 74 | 6 | 23 | | | | | | | 85 | 54 | 31 | 1 | 74 | | 30 | | 377 |
| 48 | | | 20 | <1 | 8 | | | | 19 | | | 9 | 18 | | 7 | 14 | | 86 | | 182 |
| 49 | 46 | <1 | 238 | | 17 | | | | 9 | 17 | | 64 | 111 | 66 | 51 | 236 | | 74 | | 929 |
| 50 | | | 19 | | 28 | | | | 27 | 3 | | 8 | 3 | | | 6 | | 30 | | 123 |
| 51 | | | 41 | | | | | | | | | | | 106 | | | | 106 | | 253 |
| 52 | | | | | | | | | | | | | | 1 | | | | | | 1 |
| 53 | | | | | 25 | | | | | | | | | 20 | | 2 | | | | 47 |
| 54 | | | | | <1 | | | | | | | | | 38 | | | | 16 | | 54 |
| Total | 114 | 174 | 1338 | 35 | 1257 | | | | 335 | 794 | 122 | 559 | 1461 | 1438 | 1379 | 1640 | | 2066 | | 12767 |

Table 4. Comparison of field and satellite image classifications for randomly-located sites. Vegetation was sampled along a 400-m transect. Length is the transect length (m) that passed through a polygon in the satellite image of given spectral class. Transects were located in the Initial Point, Coyote Butte, Christmas Mountain, and Bigfoot Butte quadrangles. Class IIA1 is a general grass/exotic annual classification and includes classes IIA, IIB, and IIC.

| Transect | Field Class | Satellite Image Spectral | Length | Class |
|---|---|---|---|---|
| ISA193 | IIA1 | 25 | 73.147 | IIA1 |
| ISA213 | IA5 | 19 | 6.047 | IA5 |
| | | 22 | 60.444 | IA5 |
| | | 40 | 60.452 | IC2 |
| | | 47 | 90.677 | IA3 |
| | | 50 | 182.362 | IA4 |
| ISA215 | IB2 | 10 | 197.277 | IB2 |
| | | 13 | 21.682 | IC3 |
| | | 14 | 180.831 | IB2 |
| ISA221 | IC3 | 13 | 185.286 | IC3 |
| | | 14 | 12.209 | IB2 |
| | | 17 | 114.350 | IB2 |
| | | 21 | 88.092 | IC3 |
| ISA224 | IC3 | 17 | 294.118 | IB2 |
| | | 19 | 105.905 | IA5 |
| ISA229 | IIC1 | 17 | 93.197 | IB2 |
| | | 21 | 26.636 | IC3 |
| | | 25 | 121.817 | IIA1 |
| | | 27 | 158.353 | IIA1 |
| ISA232 | IB2 | 2 | 10.259 | IB2 |
| | | 10 | 43.863 | IB2 |
| | | 14 | 302.742 | IB2 |
| | | 17 | 43.114 | IB2 |
| ISA239 | IB2 | 14 | 264.733 | IB2 |
| | | 17 | 135.215 | IB2 |
| ISA244 | IA5 | 19 | 259.160 | IA5 |
| | | 22 | 140.603 | IA5 |
| ISA255 | IA5 | 14 | 76.710 | IB2 |
| | | 19 | 279.737 | IA5 |
| | | 22 | 43.365 | IA5 |
| ISA300 | IIC1 | 27 | 136.006 | IIA1 |
| | | 29 | 86.368 | IIA1 |
| | | 34 | 91.362 | IC2 |
| | | 36 | 86.368 | IIA1 |
| OTA035 | IB2 | 26 | 68.896 | IA4 |
| | | 29 | 289.879 | IIA1 |
| | | 31 | 41.037 | IA3 |
| OTA042 | IB2 | 16 | 21.334 | IA3 |
| | | 29 | 34.048 | IIA1 |
| | | 34 | 87.755 | IC2 |
| | | 36 | 152.472 | IIA1 |
| | | 48 | 104.469 | IIC1 |

Table 4. Continued.

| Transect | Field Class | Satellite Image Spectral | Length | Class |
|---|---|---|---|---|
| OTA074 | IIC1 | 37 | 210.973 | IIB1 |
| | | 43 | 95.189 | IA4 |
| | | 47 | 95.068 | IA3 |
| OTA142 | IIC1 | 29 | 102.423 | IIA1 |
| | | 34 | 220.296 | IC2 |
| | | 37 | 77.151 | IIB1 |
| OTA195 | IC2 | 19 | 47.634 | IA5 |
| | | 22 | 97.024 | IA5 |
| | | 26 | 142.902 | IA4 |
| | | 29 | 112.564 | IIA1 |
| OTA218 | IB2 | 19 | 104.479 | IA5 |
| | | 22 | 170.614 | IA5 |
| | | 24 | 49.253 | IC3 |
| | | 36 | 75.547 | IIA1 |
| OTA222 | IC2 | 24 | 200.492 | IC3 |
| | | 26 | 30.684 | IA4 |
| | | 27 | 111.407 | IIA1 |
| | | 31 | 57.378 | IA3 |
| OTA316 | IB1 | 37 | 10.610 | IIB1 |
| | | 38 | 150.851 | IA2 |
| | | 41 | 181.000 | IA3 |
| | | 45 | 57.564 | IA3 |
| OTR050 | IC2 | 25 | 67.556 | IIA1 |
| | | 27 | 234.949 | IIA1 |
| | | 29 | 97.758 | IIA1 |
| OTR153 | IC2 | 43 | 369.444 | IA4 |
| | | 49 | 30.617 | IIA1 |
| OTR163 | IIC1 | 21 | 190.358 | IC3 |
| | | 25 | 136.460 | IIA1 |
| | | 27 | 72.973 | IIA1 |

Russian thistle (class IC2) was correctly classified in 65.8% (1,848 of 2,809) of the pixels in the image.

## DISCUSSION

One component of constructing the habitat map of the SRBOPA was to convert 55 spectral reflectance classes derived from an analysis of the Thematic Mapper satellite image (D. Ramsey, unpubl. report) into 55 or fewer habitat classes. The habitat classes must have 3 attributes: (1) classes should represent repeatable assemblages of plant species that dominate on a scale of 30 x 30 m (the pixel size of the original image); (2) classes should be sufficiently distinct so that field recognition is relatively easy; and (3) classes should represent major elements of the gradients in both natural vegetation and disturbance that exist throughout the site.

Our initial habitat classification contained 26 classes and fulfilled the above criteria. Each assemblage was repeated 10-65 times in the

Table 5. Error matrix of habitats classified by satellite imagery and field surveys. Table entries represent total meters along the field transects that intersected a habitat polygon in the satellite image. Class IIA1 represents a general grass category that includes classes IIA, IIB, IIC. Results include transects within the Integration Study Area.

| | Satellite Image | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Shrub | | | | | Disturb | | | Grass | |
| Field Survey | 1A2 | IA3 | IA4 | IA5 | IB2 | IC2 | IC3 | IIC1 | IIA1 | IIB1 |
| IA3 | | 898 | | | | 62 | | | 239 | |
| IA5 | | 91 | 182 | 823 | 43 | 60 | | | | |
| IB1 | 165 | 325 | | | | 127 | | | | 138 |
| IB2 | | 62 | 69 | 275 | 1502 | 88 | 71 | 104 | 631 | |
| IC2 | 66 | 455 | 1154 | 250 | | 1848 | 879 | 520 | 1750 | 271 |
| IC3 | | | | 106 | 420 | | 574 | | 130 | |
| IC1 | | 191 | 236 | | | | 60 | 340 | 11 | |
| IIC1 | | 632 | 371 | 484 | 93 | 603 | 368 | 634 | 1107 | 607 |
| IIA1 | | | | | | | | | 73 | |
| IIB1 | 62 | 8 | 167 | 60 | 21 | 39 | | | 34 | 9 |

original 379 samples, each appeared relatively distinct when plotted along canonical discriminant axes, and collectively they spanned both natural environmental gradients (e.g., from grassland to shrubland to riparian) and degrees of disturbance (from shrubland with perennial grasses to cheatgrass with Russian thistle to "urban" construction).

We classified vegetation into habitat classes but recognize also that shrubsteppe plant species may be distributed along environmental gradients independently of one another, thus forming a continuum rather than discrete floral communities (e.g., Whittaker 1962, 1967). The distribution and dynamics of vegetation over the scales of resolution at which we are working provide several reasons for classifying vegetation into distinct groups. The underlying natural environmental gradients (e.g., moisture, substrate, topography) may be spatially discontinuous. For example, basalt or lava flows, either emergent or shallow subsurface, may support a substantially different plant assemblage from deep loess soils, and the transition between the 2 substrate types may be a zone of just a few meters at their interface. At the 30 x 30 m resolution of our image, this transition appears as a sharp boundary.

Natural environmental gradients (continuous and discontinuous) are overlain by a disturbance regime that also produces sharp boundaries between different plant assemblages. The plant species that are abundant following a fire are usually quite different from those that were abundant before. Furthermore, because burned areas are now dominated by introduced alien species (e.g., cheatgrass [*Bromus tectorum*], Russian thistle) that can retard recolonization by native species, quite different plant assemblages may persist literally side-by-side for many decades. Likewise, fences that separate heavily

grazed from lightly grazed areas produce a distinct demarcation between different plant assemblages, and the boundary between them may be on the order of only tens of centimeters wide. Thus in many areas shrubsteppe habitat consists of a mosaic of large and small patches of qualitatively different vegetation types. Because variation within patches is considerably less than between patches (at a scale $\geq$ 30 x 30 m), classification (as opposed to ordination) of vegetation types is a reasonable goal of habitat description in this project.

The plant species composition and relative abundances within the classes are currently only approximate and will be revised as more vegetation samples are collected. It is likely that the annual component (exotic annuals, mustards, and other forbs) will vary in its expression from year to year, depending on the timing and amount of precipitation. How this variation will affect our ability to classify new samples is unclear, but it may become necessary to combine classes after more data become available. Nevertheless, we think that these categories are sufficiently distinct that with only a little training observers will be able to classify these habitat types in the field.

Previous attempts to classify vegetation in desert rangelands from satellite imagery have not been very accurate. Although percent cover of vegetation and amount of photosynthetic material influence spectral qualities, the amount of vegetation is small in desert rangelands relative to other influences on spectral signatures. In addition, increased structure of the vegetative community further decreases the linear relationships of vegetation with spectral value (Wardley and Curran 1984, Ustin et al. 1985, Bailey and Hogg 1986). Because of many influences, we do not know the upper limits on accuracy in classifying vegetation in desert rangeland from satellite imagery. Possibly, we may need to lump some vegetation categories, such as medium and high density Russian thistle, because of our inability to separate these in the image.

Much of our error in classifying vegetation may be due to using a relatively large buffered region around a point or line to account for potential locational errors. Classification of a 100-m radius circle or 400-m segment that may actually contain several small habitat patches entirely as a single habitat may create errors when overlaying with the finer resolution (30-$m^2$) of the satellite image. The actual scale of the satellite image and also of habitats in the field may be much smaller. In 1992, we will obtain points to train the image that are within 50-m of a contiguous habitat type. By relating field and image results on a 1:1 pixel scale, we may be able to better delineate habitat classes.

## PLANS FOR NEXT YEAR

We will continue to refine the habitat map integrating both local and global changes in pixels based on our current habitat classification. The accuracy of this map will be assessed by an error matrix and field results from 1991 vegetation surveys. We will reclassify habitats and update the habitat map before 1992 field seasons begin.

A second GIS layer of habitat attributes will be developed from georeferenced points of vegetation surveys. Habitat characteristics, such as percent vegetative cover, will be contoured between survey points by kriging functions. This map may provide useful information in interpreting the satellite image.

Additional scenes from different years and seasons will be used to provide ancillary information to classify the satellite image. Seasonal variation in vegetation characteristics and fire scars (Knick 1991 this volume) may be useful in separating habitat types.

**Image Reclassification**

Spectral classes that are directly correlated with habitat class on the global scale will be deleted from the original set of spectral data to remove variation attributed to that source. The spectral data will be reclassified and further refined for the remaining spectral classes. New data sets will allow comparison and further training of the GIS Image.

**Anticipated Data**

Approximately 450 sites will be randomly selected and sampled in the Integration Study Area and the Orchard Training Area (OTA) by Study 5 of the BLM/IDARNG Research Project (Knick 1990, 1991 this volume). Studies 1 and 2 will record the vegetation at study site locations and delineate distinct vegetation boundaries on 1:24,000 maps (Strickler this volume, Marzluff et al. this volume). Study 4 will sample vegetation on each of the 22 grids established for assessment of population dynamics of Townsend's ground squirrels (*Spermophilus townsendii*) (Van Horne et al. this volume). The Global Climate Change Study will sample sites within the SRBOPA but outside of the ISA.

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Appendix 1. Common and scientific names, and 4-letter codes for plant species listed in tables.

| Common Name | Scientific Name | Code |
|---|---|---|
| Big Sagebrush | *Artemisia tridentata* | ARTR |
| Bottlebrush Squirreltail | *Sitanion hystrix* | SIHY |
| Bur Buttercup | *Ranunculus testiculatus* | RATE |
| Bud Sage | *Artemisia spinescens* | ARSP |
| Cheatgrass | *Bromus tectorum* | BRTE |
| Crested Wheatgrass | *Agropyron cristatum* | AGCR |
| Gray Rabbitbrush | *Chrysothamnus viscidiflorus* | CHVI |
| Greasewood | *Sarcobatus vermiculatus* | SAVE |
| Green Rabbitrush | *Chrysothamnus nauseosus* | CHNA |
| Halogeton | *Halogeton glomeratus* | HAGL |
| Nuttall's Saltbush | *Atriplex nuttallii* | ATNU |
| Peppergrass | *Lepidium perfoliatum* | LEPE |
| Russian Thistle | *Salsola iberica* | SAKA |
| Sandberg's bluegrass | *Poa secunda* | POSA |
| Shadscale | *Atriplex confertifolia* | ATCO |
| Six Weeks Fescue | *Festuca octoflora* | FEOC |
| Tall Tumblemustard | *Sisymbrium altissimum* | SIAL |
| Tansymustard | *Descurainia pinnata* | DEPI |
| Winterfat | *Ceratoides lanata* | CELA |

# Implications of Communal Roosting by Common Ravens to Operation and Maintenance of Pacific Power and Light Company's Malin to Midpoint 500-kV Transmission Line

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*Annual Summary*

*Ravens used 3 of 4 roosts on the Pacific Power and Light Company's 500-kV transmission line between May and October, 1991. Two of the roosts are receiving significant levels of use. Rubber insulators installed at 1 of these roosts will continue to be monitored for their effectiveness in shedding fecal contamination.*

## OBJECTIVE

Monitoring was conducted to determine use of transmission line towers and levels of fecal contamination deposited by common ravens (*Corvus corax*) at 4 roosts on Pacific Power and Light (PPL) Company's Malin to Midpoint 500-kV transmission line.

## INTRODUCTION

Initial Point (Mile 113) and Marsing Dump (148/2-150/2) had been determined to be significant communal raven roosts during past studies (Young and Engel 1988, Haas 1990). They are spring to fall roosts with the height of use typically occurring in mid-summer to early fall. Succor Creek (Mile 162) was included in the monitoring due to heavy contamination on tower 162/5 discovered during line maintenance. Alkali Flat (160/3) roost was only known to have been used once in 1985 (Young and Engel 1988); however, it was monitored incidentally since it is on the route to Succor Creek.

## METHODS

The 4 roost sites were monitored between 28 May and 31 October 1991. In May and October the glass bell string insulators at each tower were photographed, and contamination was rated as to the level of buildup of fecal material following a modified system of Young and Engel (1988). Towers where insulators were free of opaque covering were rated a "0". A score of "1" was assigned when the insulator was less than 10% covered. Opaque cover in the 10-50% range rated a "2" and more than 50% rated a "3". A median score was assigned for each tower. A rating of "2" or "3" means there is potential for a line trip due to moisture associated with fecal buildup.

Initial Point and Marsing Dump towers were checked once a month for signs of recent raven activity (i.e., fresh fecal matter, pellets, feathers). If sign was observed, an evening roost count was conducted. During counts an observer with a spotting scope was positioned approximately 500 m from

the line. Beginning 30 min before sunset, the number of ravens on each section of each roost tower (following Young and Engel 1988) was counted at 10-min intervals. Observations concluded 30 min after sunset or when it became too dark to count, whichever came last. The highest number of ravens observed during any single 10-min interval was considered the night's count for the roost.

Roost counts were made at Succor Creek in May and June. The insulators at this roost were originally scheduled to be changed to those made of a polymer material in June and their effectiveness to be monitored from July to October. The insulators were not changed until October, and no visits were made to the area in July and August. In September, October, and December roost counts were done and insulator contamination was rated and photographed. Towers 163/1 and 163/2 were added to the monitoring in October. The Alkali Flat roost tower was checked for signs of use during each visit to Succor Creek.

## RESULTS

### Initial Point

On 28 May, during the first ground inspection, tower 113/1 appeared moderately contaminated with old fecal matter on the insulators and tower and rated a "3". Towers 113/2 to 113/5 had no significant contamination. On 6 June 113/1 had much fresh fecal matter and pellet castings on the ground below the tower. The other towers showed no sign of use. No ravens were seen at miles 112 through 114 during a roost count on 22 June other than a family at their nest (113/5). No sign of recent use was observed during visits to the area on 21 July and 17 August. No ravens were seen in miles 112 through 114 during roost counts on 17 August and 20 September other than 2 ravens at an old nest. On 24 October there was no sign of recent use at the towers, and no roost count was conducted.

There was a definite loss of fecal material at all towers of the Initial Point roost between May and October, probably due to weathering. Comparison photographs of the insulators on the towers from May and October show a decrease in fecal material. Tower 113/1 was rated a "3" in the spring and a "2" in the fall. Tower 113/2 decreased from a "1" to a "0". Towers 113/3 and 113/4 remained at "0". Tower 113/5 stayed at a "1". The small degree of change at 113/5 was not detected by the scoring method.

### Marsing Dump

During a pre-study field trip on 29 April, tower 148/5 had light contamination that appeared old, and tower 149/1 was clean. On 28 May all the towers at this site (148/2 to 150/2) rated "0" although tower 148/5 had light contamination that did not appear fresh. Tower 150/1 insulators showed light contamination under a red-tailed hawk (*Buteo jamaicensis*) nest occupied by 3 chicks. No signs of raven use were seen during an inspection on 30 June. On the morning of 21 July approximately 70 ravens were seen on the ground near tower 148/5. The insulators and ground around this tower as well as 148/3 and 149/1 showed fresh fecal matter. Tower 149/1 had heavy fecal buildup on some of the central strings. A roost count on 26 July recorded 167 ravens on towers 148/5 and 149/1, with most on 148/5. On 29 August there were 209 ravens using 148/3 to 149/1, most of which were on 148/4 and 148/5. On 21 September 307 ravens used towers 148/2 to 149/2, with most on 148/2, 148/3, 148/5, and 149/1. No ravens were present on the evening of 31 October. Field examination that day showed light contamination on towers 148/2 to 148/5. Approximately 30 to 50 fresh pellets were found below 148/2 and 148/5, but there was no fecal matter on the ground. The ravens appeared to space themselves fairly evenly

through the tower sections above the insulators. When all counts are combined, 96% of the ravens roosted above the insulators. The high count always occurred at 30 min after sunset.

Comparison photographs of insulators from May and October show an increase in fecal material on towers 148/2 to 148/5, which were rated a "1" in the fall. Although ratings increased there was a definite loss of fecal material on these towers due to weathering. The photographs show small, scattered blotches of opaque rather than the solid blotches seen with fresh material. This indicates that the towers would probably have been rated a "2" if scored before the October storms. This is also true for tower 149/1 which stayed at "0" even though it would have rated as a "2" in July. Towers 149/2 to 150/2 remained at "0".

**Succor Creek**

On 29 April tower 162/1 was examined during a pre-study field trip. All 6 strings were heavily contaminated (at least a "2" rating), and the ground below the tower was littered with fresh fecal matter, pellets, and feathers. On 12 May 78 ravens roosted on 162/1. No ravens roosted on the other 4 towers of mile 162. At least 60 of these ravens were counted on the ground north of tower 162/2 1 hr before sunset, among a herd of cattle. On 9 June only 1 raven was seen on 162/2, 20 min after sunset, and it left the area before complete darkness. On 26 September field inspection showed no recent use of mile 162. The contamination seen on 162/1 in April had faded considerably and was rated a "1". Towers 162/2 to 162/4 rated a "0". Tower 162/5 had porcelain insulators and was not rated. There were many old bones and pellets, but no fresh fecal matter, below the tower. No ravens used mile 162 during that evening's roost count; however 78 ravens were using tower 163/1 and 41 were on 163/2. Mike Mulrooney of PPL conducted a roost count the previous evening and recorded 296 ravens on 163/1 and 51 ravens on 163/2.

On 9 October insulators on towers 162/5 to 163/2 were replaced with smaller diameter, black rubber insulators. It is hoped that the rubber insulators will be more effective in shedding excrement than the glass or porcelain ones. Fecal contamination was already apparent on the new insulators on 17 October. Tower 163/1 was receiving the heaviest use with much fresh feces on insulators, tower, and ground. Tower 163/2 appeared to be receiving slightly less use and 162/5 light use. On 24 October towers 162/1 to 163/2 were inspected and observed for roosting ravens. No change in contamination was noted for any of the towers. No ravens roosted on mile 162 towers while 104 ravens roosted on 163/1 and 109 on 163/2. On 16 December towers 162/5, 163/1, and 163/2 were inspected and towers 161/5 through 163/2 were observed for roosting ravens. Very little recent use was evident on the inspected towers and previous feces had weathered away. Forty-eight ravens roosted on tower 161/5 that evening. On 5 January 1992, the area was visited 1 hr before sunset, but a roost count was not conducted. Approximately 105 ravens were perched on the ground a few hundred m north of tower 162/1.

**Alkali Flat**

Tower 160/3 was inspected on 12 May, 9 June, 26 September, and 24 October. The insulators and tower were very clean each time with no sign of avian use. In addition towers 159/1 to 160/4 were checked in passing after each roost count at Succor Creek, and no ravens were seen.

## DISCUSSION

The 1991 monitoring was low in intensity, and the data gathered are insufficient for quantitative analysis of tower use at

individual roosts. However, relative level of use at each roost is apparent from the data. Marsing Dump and Succor Creek were occupied by large groups of ravens. Mile 113 of the Initial Point roost did not receive significant use and Alkali Flat was not used.

Historically, the Initial Point roost has included miles 106 to 113 with miles 107 to 112 receiving the heaviest use (Young and Engel 1988). Towers 107/2 to 112/4 were fitted with shields and pegging in 1989 which are effectively preventing insulator contamination (Haas 1990). In 1989 and 1990 mile 113 was monitored incidentally during biweekly (Beck 1989) and monthly (Haas 1990) roost counts for miles 107 to 112. No raven roosting activity was noted. In addition, no roosting occurred on towers 112/3 or 112/4 in 1989 and on mile 111 through 112 in 1990.

In 1991 no roosting activity was seen for mile 112 through 114 although tower 113/1 received some use in the past year as well as between 28 May and 6 June 1991. This tower was contaminated enough to warrant concern and should continue to be monitored. A yearly examination of fecal buildup in the fall should be sufficient. This tower may only receive late winter to late spring use, in which case normal weathering may reduce contamination to an acceptable level before the critical late fall moisture conditions. Outages occur when contaminated insulators have been moistened through prolonged exposure to fog or light, misting rain (Young and Engel 1988).

Marsing Dump has been known to be a significant communal roost since at least 1984. Roost counts in 1984 and 1985 recorded roughly 600 ravens and 300 to 360 ravens in 1986 and 1987 (Young and Engel 1988). Haas (1990) reported counts of 156 ravens for 22 August and 12 ravens for 25 October 1990. She noted moderate to heavy accumulation of feces for towers 148/2 to 149/2 and recommended shields for those towers. Interestingly, she noted a sharp increase in contamination between June and late July as was also seen in 1991.

In 1991 roosting activity appeared to peak in September when 307 ravens were counted. Over the survey period towers 148/2 to 149/1 received the heaviest use. Only contamination on 149/1 in late July was serious enough to warrant concern for the line's operation. Towers 148/4 and 148/5 probably also had significant contamination, but normal weathering reduced contamination on all the heavy use towers to nonsignificant levels by late October. Line trips, flashovers, and other problems sometimes caused by fecal contamination have not occurred at this site. This roost is likely to continue to receive use, and raven numbers can be expected to fluctuate along with the local raven population level. Continued monitoring will help detect any rise in future use that may warrant rubber insulator or shield application. If this roost starts to be used in the winter, as is the nearby Marsing Southwest site (mile 153-156), then contamination will likely be a problem. A combination of ground inspection and weekly roost counts during September and October should be sufficient to understand conditions going into the moist season.

Historical information for the Succor Creek area is lacking because it was not included as a part of Young and Engel's study area (1988). During past line maintenance tower 162/5 was found to have several burned insulators caused by flashovers as a result of fecal buildup. From data gathered this year towers 162/5 to 163/2 apparently comprise an important roost site. In addition, tower 162/1 had received significant use in the early part of this year, and tower 161/5 was used in winter. Tower 161/5 has not been inspected. A roost count, tower 161/5 inspection, and evaluation as to effectiveness of the rubber insulators will be done in February. This site should continue

to be monitored in 1992. Roost counts and ground inspection in the fall would probably be sufficient.

Alkali Flat, from 159/1 to 160/4, is not receiving any raven use and does not need to be monitored in the future unless routine line inspection indicates some use.

## MANAGEMENT RECOMMENDATIONS

The following recommendations are based on the results of the 1991 monitoring:

Conduct a roost count and tower inspection at Succor Creek in February 1992.

Conduct fall 1992 monitoring at tower 113/1 of Initial Point, at towers 148/2 to 149/2 of Marsing Dump, and at Succor Creek towers 161/5 through 163/2. This should begin in September and include inspection of insulators, tower, and ground for evidence of use and weekly roost counts when use is indicated.

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# Use of Nest Boxes by American Kestrels in Southwestern Idaho

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*Annual Summary*

*American kestrels (Falco sparverius) nested in 24 boxes along I-84 and in the vicinity of Kuna, Idaho in 1991. Occupancy rates (46%) were higher than in all previous years, but nesting success rates (66%) were lower than in 1990. Sixty-eight kestrels were banded in 1991, and 2 adult females banded in 1990 were recaptured in the same boxes they had used in 1990.*

## OBJECTIVES

1. Determine kestrel occupancy rates and nesting success at boxes erected in southwestern Idaho.

2. Mark nestling and adult kestrels to accumulate baseline data for future studies on dispersal and population dynamics.

## INTRODUCTION

This study began in 1985 when nest boxes were erected on abandoned power poles in the Snake River Birds of Prey Area in an effort to learn more about the food habits and breeding biology of American kestrels (*Falco sparverius*) in southwestern Idaho (Steenhof et al. 1985). The limited use of those boxes prompted curiosity about factors that influence occupancy rates. In 1986, the Idaho Fish and Game Department's Nongame program joined the study, and the study area expanded to include agricultural and suburban habitat in the Kuna area as well as Interstate 84 between Simco Road and Caldwell. In 1991, BLM had sole responsibility for monitoring the boxes

## METHODS

Boxes have been erected for kestrels in 3 separate study areas in southwestern Idaho: on trees within agricultural habitat in the vicinity of Kuna, Idaho (hereafter referred to as the Kuna Route); on highway signs along Interstate 84 between Simco Road and Caldwell (hereafter referred to as the I-84 Route); and on abandoned power poles along the north rim of the Snake River Canyon (hereafter referred to as the BOPA route). Monitoring in 1991 focused on the boxes on the Kuna and I-84 routes because of high vandalism and low kestrel occupancy rates on the BOPA route (Steenhof 1989). In 1991, 28 boxes were available on the I-84 route, and 24 were available on the Kuna route. Several boxes on both routes have been destroyed since the study began.

Most boxes were checked in mid-April, and we repaired boxes and added shavings at that time. Six boxes on the Kuna route were

re-positioned during our April check either because they had been vandalized or because low occupancy rates in past years suggested that the site was not suitable for occupancy. All boxes on the Kuna route and I-84 route were checked again in late May or early June. All boxes with viable nesting attempts were re-visited as necessary to band young and ascertain nesting success. Nests with young that could be sexed (75% feathered) were considered successful. Investigators checked boxes while standing on a ladder. When checking boxes, investigators inserted a hole stuffer into the nest box entrance to trap any adult birds in the box. Adults and young were weighed with a 300-g Pesola balance. Nests of European starlings (*Sturnus vulgaris)* were removed in an effort to keep all boxes suitable for kestrel nesting.

## RESULTS

Twenty-four (46%) of 52 available boxes on the Kuna and I-84 routes were used for nesting by kestrels in 1991. The 1991 box occupancy rate was higher than the rates observed on these 2 routes in all past years (Table 1). Occupancy rates on the I-84 and Kuna route (58%) were higher than occupancy rates of I-84 boxes (36%) in 1991, but differences were not significant. The number of boxes occupied by kestrels on the Kuna route increased from 10 in 1990 to 14 in 1991, while the number of occupied I-84 boxes remained at 10. Along I-84, the number of occupied boxes west of Meridian declined from 7 in 1990 to 6 in 1991, while the number east of Boise increased from 3 to 4.

Three boxes were used by kestrels for the first time in 1991. Fifteen of the boxes used by kestrels had been used in 1990, 2 were last used in 1989, 1 was last used in 1988, and 3 were last used in 1987. Kestrels laid eggs in 3 of the 6 boxes that we re-positioned in April, but none of the eggs hatched.

Overall nesting success of 24 kestrel pairs in 1991 was 67%, a decline from 1990's success rate of 84% (Table 2). Seventy percent of I-84 nests were successful, and 64% of nests on the Kuna route were successful. All 8

Table 1. Occupancy rates of kestrel boxes on the Kuna and I-84 routes, 1986-1991. Number of available boxes in parentheses.

| Year | I-84 | Kuna | Overall |
|---|---|---|---|
| 1986 | 24% (17) | 18% (17) | 21% (34) |
| 1987 | 41% (32) | 39% (31) | 40% (63) |
| 1988 | 30% (30) | 40% (30) | 35% (60) |
| 1989 | 28% (29) | 27% (30) | 27% (59) |
| 1990 | 36% (28) | 38% (26) | 37% (54) |
| 1991 | 36% (28) | 58% (24) | 46% (52) |

Table 2. Percent of kestrel nests successful on the Kuna and I-84 routes, 1986-1991. Sample sizes in parentheses.

| Year | I-84 | Kuna | Overall |
|---|---|---|---|
| 1986 | 0% ( 3) | 100% ( 4) | 57% ( 7) |
| 1987 | 54% (13) | 55% (11) | 54% (24) |
| 1988 | 44% ( 9) | 50% (12) | 48% (21) |
| 1989 | 25% ( 8) | 75% ( 8) | 50% (16) |
| 1990 | 80% (10) | 89% ( 9) | 84% (19) |
| 1991 | 70% (10) | 64% (14) | 67% (24) |

unsuccessful nests failed during incubation; most failures were attributed to abandonment. Seven of the 16 successful nests had at least 1 egg which failed to hatch, and nestlings died at an additional site. A fully-feathered (25-day old) male died in captivity after having been taken from a nest box in severely emaciated condition. Four healthy female young were in the box, and the male's head had been pecked severely. Observed clutch sizes ranged from 2 to 6 in 1991 (mean and mode = 5). We observed broods of 6 for the third consecutive year.

We banded 68 kestrels in 1991 (60 nestlings and 8 adults). Of the adults banded, 6 were females, and 2 were males. We also re-captured 2 females banded in 1990--1 on the I-84 route, and 1 on the Kuna route. Both were nesting in the same boxes where they had nested in 1990. Three of the adult females captured in 1991 were in boxes where other females had been caught and banded in either 1987 (2) or 1988 (1). All other adults were caught in boxes where adults had not been previously banded.

Starlings nested in 24 of the 52 boxes in 1991, and house sparrows (*Passer domesticus)* nested in 3 boxes. Only 4 boxes had no confirmed use by any species during the nesting season. All house sparrow nests were on the Kuna route. Starling occupancy rates were highest along the I-84 route, where 20 of 28 boxes (71%) were used by starlings. Kestrels took over 1 of the I-84 boxes used by starlings, and starlings nested in another I-84 box after kestrel eggs were abandoned. On the Kuna Route, starlings nested in only 4 boxes (17%); 1 of these boxes had been used by house sparrows, was moved, and was later occupied by starlings.

Weights of adult females ranged from 120 to 162 g and averaged 142 g ($\underline{n}$ = 6; SD = 18). One adult male weighed 115 g.

## ACKNOWLEDGMENTS

This study could not have been completed without the field assistance of Lorna Ritter, Barbara Stuart, Gerald Griggs, and Genna Poulson. We are especially indebted to the landowners in the Kuna area who graciously allowed us to set up and check boxes on their property. The National Geographic Society donated a ladder to the study.

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# Feeding Ecology of the Barn Owl in the Snake River Birds of Prey Area

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*Annual Summary*

*Surveys of 15 traditional barn owl nest/roost sites revealed that site occupancy remained at the low levels observed for the past 6 years. However, 1 more site was occupied than in 1990. Diet data revealed pronounced changes in several major prey, of which the 17% increase in voles was most significant.*

## OBJECTIVE

To determine food-niche parameters and food-niche variation among collection sites and among years for barn owls (*Tyto alba*) nesting in the Snake River Birds of Prey Area (SRBOPA).

## METHODS

Owl diet data originated from regurgitated pellets that I collected at cliff sites occupied by barn owls. Most sites were occupied barn owl nests. All collections were made from March to August. Prey in the pellets were identified and quantified by standard methods (Marti 1987). See Marti (1988) for treatment of data from earlier years.

## RESULTS AND DISCUSSION

Pellet samples were collected at 5 sites from 6-12 June. Collection locations and sample sizes are given in Table 1. The 1991 dietary

Table 1. Collection sites for barn owl diet data and number of prey in collection samples from the SRBOPA, 1991.

| Collection Site | Number of Prey in Samples | |
|---|---|---|
| | 6 June | 12 June |
| Jensen Cliff | | 102 |
| Castle Rock Cave | | 214 |
| Lower Lower Black Butte | 75 | |
| Upper Lower Black Butte | 435 | |
| Garbage Draw | 78 | |

sample is summarized in Table 2. Vole (*Microtus montanus*) frequencies in the diet increased by 17% over 1990, reversing the downward trend of the preceding 3 years (Marti 1990). Several other major prey declined in the diet sample from the 1990 frequencies. Most striking was the 10% decrease in *Thomomys townsendii*.

Five sites were active in 1991, 1 more than in 1990. See Marti (1990) for comparisons of the number of occupied sites and size of diet samples in other years.

## PLANS FOR 1992

Three trips to the SRBOPA are planned for the spring/summer of 1992. The objectives for 1992 are to continue collecting food habits data for the analysis of long-term predation trends by barn owls and to monitor trends in breeding numbers of barn owls.


## ACKNOWLEDGMENTS

I thank Richard Olendorff, Michael Kochert, Karen Steenhof, John Doremus, Gerry Griggs, and all of the Snake River Birds of Prey Research staff for a variety of assistance in carrying out this study. The Bureau of Land Management provided a vehicle for field use and living space in field camps. Weber State University provided a Faculty Research Grant covering travel to the study area from Ogden, Utah, and laboratory space and computer facilities for data analysis.


Table 2. Total prey identified for the barn owl in the SRBOPA, 1991.

| Prey species | | Number | Percent number |
|---|---|---|---|
| MAMMALS | | | |
| | *Sorex vagrans* | 3 | 0.3 |
| | *Mus musculus* | 83 | 9.2 |
| | *Peromyscus* spp. | 88 | 9.7 |
| | *Reithrodontomys megalotis* | 77 | 8.5 |
| | *Microtus montanus* | 567 | 62.7 |
| | *Perognathus parvus* | 2 | 0.2 |
| | *Dipodomys ordii* | 21 | 2.3 |
| | *Thomomys townsendii* (juvenile) | 51 | 5.6 |
| BIRDS | | | |
| | *Sturnus vulgaris* | 1 | 0.1 |
| | unidentified icterid | 2 | 0.2 |
| | unidentified medium bird | 2 | 0.2 |
| | unidentified small bird | 7 | 0.8 |
| Totals | | 904 | 100 |

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# Raptor Use of Nest Boxes in the Snake River Birds of Prey Area

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Annual Summary

*Seventy nest boxes were available at 34 sites for raptor roosting and nesting in 1991. Twenty-six of the available sites were utilized by raptors as roosting or breeding sites.*

## OBJECTIVES

1. To determine patterns of nest box use, fidelity to site and mate, reproductive success, food habits and the annual body mass in western screech-owls (*Otus kennicottii*).

2. To determine productivity, mating system and breeding season diet of northern saw-whet owl (*Aegolius acadicus*).

## METHODS

Nest boxes were visited monthly from January through May and in October and November. Boxes with breeding saw-whet owls were visited in late April and May to band the young. Sites with breeding screech owls were scheduled to be visited the second week in May, but illness of the investigator did not allow this visit to be made. By the third week in May several of the broods were gone from the boxes and were not banded. No attempts were made to band the kestrels. Adult female saw-whet owls were captured in the nest boxes, and the males were caught in a mist net as they brought prey to the female and brood.

Western screech-owls were captured throughout the year in the boxes. All adult-size owls were weighed with a Pesola 300-g spring scale, and unbanded owls were banded. After fledging all prey remains were removed from the boxes for food habits analysis.

## RESULTS

Western screech-owls utilized 21 of 34 available sites during 1991 (Table 1). Eleven of the 21 sites were used for breeding attempts. The Delta West site failed to hatch any young, and the River Road site was vandalized and probably failed to produce young. The fledging success was undetermined at 2 sites as the young were gone before they could be banded. At the remaining 7 sites the owls laid 32 eggs and produced at least 28 young.

Northern saw-whet owls attempted to breed at 6 sites during 1991. Thirty-four eggs were laid at these sites. Two sites each with 5 eggs were unsuccessful at fledging young. The 3 successful sites contained 17 young at banding. A site where the success was not determined had 4 young at banding.

American kestrels attempted to breed at 7

Table 1. Location and status of roosting/nesting boxes available to raptors in the Snake River Birds of Prey Area, 1991.

| Location Name | Status[a] | Nesting Success |
|---|---|---|
| BOPA East Boundary | vacant | |
| Black Butte, Lower Lower | AK breeding | unknown success |
| Black Sands III | WSO breeding | successful |
| Bruneau Boat Launch | NSO breeding | successful |
| | WSO roosting | |
| Bruneau Marsh | WSO breeding | successful |
| Bruneau Marsh North | WSO roosting | |
| Bruneau Marsh South | AK breeding | unsuccessful |
| Bruneau Marsh West | vacant | |
| Bruneau Rest Stop | vacant | |
| Bruneau River[b] | NSO breeding | successful |
| | WSO roosting | |
| Cabin | AK breeding | unknown success |
| | WSO breeding | successful |
| Castle Creek Mouth North IV | WSO breeding | successful |
| Castle Creek Mouth North | AK breeding | Unknown success |
| Cellar Hole | WSO breeding | unknown success |
| | AK breeding | unknown success |
| Crane Falls Sturgeon | WSO breeding | unknown success |
| Delta East | vacant | |
| Delta South | NSO breeding | unsuccessful |
| Delta West | WSO breeding | unsuccessful |
| Flat Iron Marsh | vacant | |
| Harris | AK breeding | unknown success |
| | WSO roosting | |
| Jack's Creek | WSO roosting | |
| Little Valley School | WSO breeding | unknown success |
| Loveridge Bridge | vacant | |
| Orcutt Treeline | WSO roosting | |
| Rabbit Springs | NSO breeding | successful |
| River Road | WSO breeding | unknown success |
| Strike Camp | vacant | |
| Strike Camp Treeline II | NSO breeding | unknown success |
| Strike Dam | WSO roosting | |
| Strike Dam Marsh[b] | vacant | |
| Strike Ditch | WSO roosting | |
| Strike Reservoir | WSO roosting | |
| Three Forks | WSO breeding | unknown success |
| | NSO breeding | unsuccessful |
| Tom Draw | WSO breeding | unknown success |
| Two Forks | WSO roosting | |

[a] AK = American kestrels; WSO = Western screech owl; NSO = Northern saw-whet owl.

[b] New sites available in 1991.

sites. Two sites failed during incubation, and the fate of the remaining 5 sites is unknown.

Thirty-seven screech-owls (14 nestling, 5 female, 1 male, and 17 screech owls of unknown sex), and 30 saw-whet owls (21 nestling, 5 female, and 4 male) were banded during 1991. A female saw-whet owl banded at her nest site in 1990 returned to breed at a nearby site in 1991. This is the first time in this study that a banded saw-whet owl has been recovered in a subsequent year.

Seventy-one screech-owl body mass measurements were obtained from adult-sized owls. The 20 female weights taken

outside the breeding season ranged from 191-279 g. Ten body mass measurements for females taken during the breeding season ranged from 219-273 g. Thirteen body mass measurements taken from male owls ranged from 157-207 g. The body mass of 28 owls of unknown sex ranged from 169-248 g.

Seven body mass measurements were obtained from 6 breeding female saw-whet owls. The female body mass ranged from 108-127 g. Four body mass measurements were obtained from 4 male saw-whet owls. The male body mass ranged from 75-80 g.

No body mass measurements were obtained from kestrels, and no kestrels were banded.

## DISCUSSION

The breeding failure of 1 screech-owl, 2 saw-whet owl and 1 kestrel pair can be attributed to inappropriately timed visits by the investigator. At the River Road site both boxes were pulled from the trees by vandals. The owl box was empty, but the kestrel was incubating her clutch in the grounded box. At the next visit the box was again on the ground, and the kestrel had deserted the site.

## PLANS FOR THE 1992 FIELD SEASON

The 1992 investigation will have the same objectives as 1991. A number of new boxes will be placed in habitat deemed suitable for saw-whet owl breeding. A graduate student will collect saw-whet owl data if any saw-whet owls nest in the study area. If funding permits radio transmitters will be placed on some adult and young saw-whet owls to investigate their movements in and around the study area.

# Wintering and Nesting Site Fidelity of Long-eared Owls in the Snake River Birds of Prey Area

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Annual Summary

*From December 1990 through June 1991 I banded 31 adult wintering owls and recaptured 5 owls, out of at least 52 long-eared owls (Asio otus) wintering at 4 sites. During the 1991 nesting season, I banded 34 juvenile owls and captured 7 adults, of which 2 were recaptures. Since January 1988 I have banded 194 owls and recaptured 9 owls a total of 12 times. Of the recaptures, 6 owls were caught in more than 1 winter at the same site, 3 owls were caught as adults in both the nesting and winter seasons at the same site, and 1 owl was captured as a nestling and wintering adult at the same site. Numbers of long-eared owls wintering in the SRBOPA in 1990-91 appeared greater than the previous 3 winters.*

## OBJECTIVES

1. To determine whether long-eared owls that nest in the Snake River Birds of Prey Area also winter there.

2. To monitor numbers of long-eared owls wintering and nesting in the Snake River Birds of Prey Area.

## METHODS

On 7 days from November 1990 through February 1991 I searched 8 traditional nesting areas to count wintering long-eared owls. I trapped winter roosting owls during the day, setting 4-cm mesh mist nets in flight paths within the roosting groves. I either flushed owls back and forth to cause them to fly into the nets, or waited for them to return on their own to their favored roost site. I weighed owls with a 300 or 1000-g pesola scale, and banded all unbanded owls. I used coloration of the remiges to determine age: a pink wash on the underside of the wings indicates freshly molted feathers, and thus an adult bird. This characteristic is best early in the winter, and fades later in the season. A more definitive characteristic is 2 tones of remiges on the top surface, which results from an adult owl not having molted all its remiges during the summer molt. The old feathers will be paler than the new feathers.

On 4 days from April through June 1991 I searched traditional nesting areas for nests. I banded young owls during the last week of the nestling period or the first 2 weeks of branching. I captured and banded adult owls during the branching or fledgling stages, using mist nets baited with a great horned owl (*Bubo virginianus*) decoy at dusk or night. I set the nets outside the nest grove, in a position so that the great horned owl decoy would be silhouetted against the sky. I weighed all adult owls, and determined sex by the presence or absence of a brood patch.

## RESULTS AND DISCUSSION

During winter 1990-91 I found long-eared owls at 4 of the 8 sites I searched. Of at least 52 owls using these sites, I caught and banded 31, and recaptured 5 owls (Table 1). There were >30 owls roosting at Tom Draw, where I have found more wintering long-eared owls in the past 3 years than at any other site. Numbers there were 7 in 1987-88, approximately 15 in 1988-89, and approximately 17 in 1989-90.

Table 1. Sites where roosting long-eared owls were found during the winter of 1990-91 in the SRBOPA. Other sites searched without success were Loveridge Bridge, Bruneau Arm, Jack Springs, Rabbit Springs, and the north side of the river below Swan Falls Dam.

| Site | Date | # Seen | # Banded | # Recaptures |
|---|---|---|---|---|
| Tom Draw | 12 Nov | >15 | --- | --- |
| Tom Draw | 9 Dec | >30 | 12 | 3 |
| Tom Draw | 2 Feb | 20-30 | 4 | 1 |
| Crane Falls | 13 Jan | 8 | 0 | 0 |
| Crane Falls | 17 Feb | 9 | 6 | 0 |
| Castle Mouth N | 20 Jan | 5 | 3 | 1 |
| Fossil Cr Mouth | 10 Feb | 8 | 6 | 0 |

Since January 1998 I have banded 194 owls and recaptured 9 owls a total of 12 times (Table 2). Three of these owls, all males, were captured as adults in both the breeding and wintering seasons, indicating that at least some male long-eared owls both breed and winter in the SRBOPA. A fourth owl was banded either as an adult female or a local nestling in Spring 1988: I mixed up the 2 band numbers at banding time and cannot now say definitely which was which. I caught 3 owls in 2 winters only. I am not sure of the sex of these birds because I can only definitely determine the sex of adult owls during the nesting season, not during the winter.

During spring 1991 I searched 10 traditional sites and 1 new site (Bruneau Flat Road) within the SRBOPA, finding 9 nests at 6 sites (Table 3). During field work for another study, I also discovered long-eared owl nests on islands in the Snake River below Swan Falls Dam. These islands are part of Deer Flat National Wildlife Refuge. I banded a total of 16 young on 4 of these islands (Current, Rippee, Center, and Becky), as well as at 6 nests in the SRBOPA. I trapped adult owls at 3 nest sites, making 2 recaptures of birds that had wintered in the SRBOPA.

Many more owls roost during the winter than subsequently nest in a site the next spring. Tom Draw had 30 wintering owls and only 2 nests. It appears, therefore, that owls at winter roosts in the SRBOPA are a mixture of local nesters and other birds. The unanswered questions are where these other owls come from, and where they nest. One possibility is that they are birds from other nesting sites in the local Snake River area, that congregate into a few communal roosts in the winter. Another possibility is that they are birds that nest in the mountains to the north, and retreat from the high snow country to the desert for the winter. It would require extensive banding operations in the mountains and the desert or radio-telemetry of wintering owls to test these hypotheses. Both may be true. I did capture 1 nesting male owl at Castle Creek Mouth North which had wintered at Fossil Creek Mouth the previous winter. These 2 sites are across the river from each other, and about 4.5 km apart. This lends some support to the first possibility.

My Master's research in 1988-89 established that almost all long-eared owls leave the SRBOPA after immediately after nesting, and at least a large proportion of them move into the forested mountains to

Table 2. Recaptured long-eared owls from January 1988-June 1991 in the SRBOPA.

| Location | Band Number | Sex | Dates Captured (Wt. in Grams) |
|---|---|---|---|
| Castle Mouth N | 816-44041 | ? | Apr 87 (juv) Jan 91 (281) |
| Tom Draw | 896-36733 | Male | Jan 88 (271) May 89 (231) Dec 90 (245) May 91 (228) |
| Tom Draw | 896-36734 | ? | Jan 88 (272) Jan 89 (248) |
| Tom Draw | 896-36735 | Male | Jan 88 (276) Jan 89 (252) May 90 (240) |
| Tom Draw | 816-74512 | ? | May 88 ("?") Jan 89 (252) |
| Tom Draw | 816-74592 | ? | Dec 89 (248) Dec 90 (268) |
| Tom Draw | 816-74599 | ? | Dec 89 (249) Dec 90 (282) |
| Tom Draw | 816-74909 | ? | Dec 90 (249) Feb 91 (250) |
| Fossil Creek | 816-74929 | Male | Feb 91 (272) May 91 (219) - at Castle Mouth N |

the north for the summer. I have searched Tom Draw, where most of my recaptures have been, in the summer without finding any owls, indicating that the owls I have caught there in both spring and winter probably also follow this pattern.

## PLANS FOR 1991-92

I plan to continue monitoring, trapping, and banding long-eared owls at as many sites as I can each winter and nesting season. Priority sites will be the ones where I trapped in previous winters and springs.

## ACKNOWLEDGMENTS

I thank John Doremus for consistently providing help, knowledge, and support for this work. I thank the many people who helped tote poles and trap owls: Peter Harrity, Willard Heck, Jane Crosby, Brian Goller, Matt McCoy, Steve Duke, Peggy Guillory, Vicki Saab, Charlie Rains, Dave Yearsley, Tom Ulmschneider, Carol Winkler, and others.

Table 3. Nests of long-eared owls in the Snake River Birds of Prey area in 1991.[a] Other sites searched with no nests found are: Bruneau Arm, Bruneau Flats, Crane Falls Lake, Crane Falls Sturgeon, and C.J. Strike Wildlife Management Area headquarters and surrounding treelines.

| Site | Adults Trapped | # Young | # Juv Banded | Fate |
|---|---|---|---|---|
| Loveridge | -- | ≥ 3 | 1 | Unknown (2 juv depredated) |
| Emigrant Trail So. Lower | -- | 5 | 5 | Unknown (branching young) |
| Strike Dam Marsh | -- | 5 | 5 | Unknown (branching young) |
| Strike Dam Marsh West | -- | ≥ 3 | 1 | Successful (2 juv depredated) |
| Strike Dam Road West | 2 | 4 | 4 | Successful |
| Strike Dam Road | 2 | Unknown | 0 | Unknown |
| Castle Ck Mouth N IV | 2 | 5 | 0 | Unknown, maybe renest |
| Castle Ck Mouth N I | 0 | Unknown | 0 | Unsuccessful |
| Tom Draw I | 0 | ≥ 1[b] | 0 | Unknown |
| Tom Draw II | 1 | ≥ 2 | 2 | Successful |
| Bruneau Flats Road | -- | 0 | 0 | Unsuccessful |

[a] In addition, Study 3 found occupied sites at Tom Draw II, Sinker Creek Mouth, and Strike Dam Marsh Green.
[b] Two eggs were also found.

# Red-Tailed Hawk Predation on Snakes: The Effects of Weather and Snake Activity

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*Annual Summary*

*Snakes are important prey for red-tailed hawks (Buteo jamaicensis). In 1991, I examined the dynamics of red-tailed hawk predation on snakes during this raptor's nesting period on the Snake River Birds of Prey Area in southwestern Idaho. I measured the rate of hawk predation on snakes through direct observation of prey deliveries to the Pump Draw red-tailed hawk nest from 10 May to 18 June for 349 hrs. The Hammett red-tailed hawk nest was also watched for 18 hrs between 4 and 19 June. Body temperature and activity patterns of 6 gopher snakes (Pituophis catenifer) implanted with activity and temperature-sensitive radio transmitters were recorded from 11 May to 20 June with telemetry equipment. Two weather stations collected meteorological data from 18 April to 20 June for analysis of the effects of weather on snake activity and red-tailed hawk predation.*

*Three hundred sixty-seven hrs of red-tailed hawk nest observations were made. Observed prey returns show that gopher snakes and racers (Coluber constrictor) made up 52.6% (73 of 142) of observed prey items delivered to the nest or eaten away from the nest by the adult hawks. These 73 snakes made up an estimated 68.5% of the hawks' total observed diet biomass. Gopher snake activity and body temperature were recorded for 4268 hrs from 11 May to 20 June.*

## OBJECTIVES

1. Examine how weather conditions and snake activity affect red-tailed hawk predation on snakes.

2. Examine how species of prey and the times of delivery to the nest vary throughout the day and nesting season.

## METHODS

My study area was on the eastern side of the Snake River Birds of Prey Area (SRBOPA), near Hammett, Idaho. Chalk Gulch, Pump Draw, Simpkin, and Hammett red-tailed hawk territories were located near Hammett. The Chalk Gulch nest was abandoned approximately 2 wks into the incubation period, between 25 April and 1 May. The Simpkin nest was also abandoned about 2 wks into the incubation period between 23 and 27 May.

We identified red-tailed hawk prey and recorded the initial time prey was observed at or near the nests. These variables were determined by observing Pump Draw and Hammett nests from a vehicle during the 1991 nesting period. Observations were made at distances of approximately 100 m with a Nikon 40-power spotting scope.

Pump Draw nest was observed from 10 May to 18 June for 349 hrs. Observation periods were 5 days/wk, usually Monday through Friday by either Tim Nichols or Tim Brown from 0700 hrs to 2100 hrs. Nest observers were switched at 1400 hrs each day. Observers would alternate from the morning period on 1 observation day to the evening period on the next. Thus, after 2 observation days, the nest was watched during all daylight hours by both observers. I watched the Hammett nest for 6 days from 1000 to 1300 hrs between 4 June and 19 June.

When recording prey deliveries, prey items were categorized as small, medium, or large within their particular species. Estimates were made on the proportion of the prey item delivered to the nest. Biomass estimates of each prey item were then determined from Steenhof (1983) and C. R. Peterson (pers. commun.).

Gopher snakes were hand-captured by searching the canyon rim and the riparian zone on both sides of the Snake River.

Captured snakes were brought to Idaho State University (ISU) where they received surgically implanted Telonics CHP radio transmitters (150 to 152 MHz) equipped with temperature and motion sensors. Gopher snakes were used because they are a major prey item (Steenhof and Kochert 1985), abundant, and large enough for transmitter implants.

The activity and body temperature of 6 gopher snakes were recorded with a multichannel radiotelemetry receiving base station, which included a Telonics receiver and signal processor, and Campbell Scientific CR10 datalogger. Snake activity and body temperature were sampled at 5-min intervals, 24 hrs per day from 11 May to 20 June for 4268 snake hrs (Table 1). All radio transmitter signals were stored in the datalogger in the field and later down loaded

Table 1. Activity and body temperature monitoring periods of 6 gopher snakes at the Snake River Birds of Prey Area, near Hammett, Idaho, 1991.

| Snake | First and Last Dates | | Days (Hrs) | |
|---|---|---|---|---|
| Arnette | 11 May | 20 June | 40 | (964) |
| Phoebe | 20 May | 20 June | 31 | (746) |
| Dexter | 20 May | 20 June | 31 | (745) |
| Trixie | 20 May | 20 June | 31 | (747) |
| Leopold | 29 May | 20 June | 22 | (535) |
| Duke | 29 May | 20 June | 22 | (531) |
| | | Total | 177 | (4,268) |

into a microcomputer for analysis.

Two weather stations, 1 on the canyon rim south of the river and another on the north river bank, collected weather data. These data included measurements of short wave radiation, wind speed, and air, soil, and snake model temperatures. Mean values were recorded at 5-min intervals with a Campbell Scientific CR10 datalogger. Short wave radiation was measured with a Li-Cor pyranometer. Wind speed was measured with a Weathertronics cup anemometer 2 m above the ground. All temperature measurements were made with thermocouples. Shaded air temperatures were measured at 1 and 200 cm above the ground. Soil temperatures were taken at the surface and at depths of 2 cm, 20 cm, and 1 m. Operative snake (model) temperatures were measured with appropriately painted, 30.5 cm x 2.5 cm copper tubing (Peterson 1987) placed on rock and dirt locations that were exposed to sunlight.

## RESULTS AND DISCUSSION

Observed prey deliveries of the Pump Draw adults included 49 gopher snakes, 24 racers, and 1 striped whipsnake (*Masticophis taeniatus*). Gopher snakes and racers made up 52.6% (73 of 142) of observed prey items delivered to the nest or eaten away from the nest by the adult hawks (Fig. 1), and they comprised 68.5% of the hawks' total observed diet biomass (Fig. 2). Miscellaneous mammals included 2 Townsend's ground squirrels (*Spermophilus townsendii*), 2 pocket gophers (*Thomomys* sp.), 9 kangaroo rats (*Dipodomys* sp.), and 5 unidentified mammals. Rabbits included 5 mountain cottontails (*Sylvilagus* sp.), 1 black-tailed jackrabbit (*Lepus californicus*), and 1 white-tailed jackrabbit (*Lepus townsendii*).

The Hammett nesting pair delivered 13 prey items to the nest during the observation periods. These included 4 gopher snakes, 1

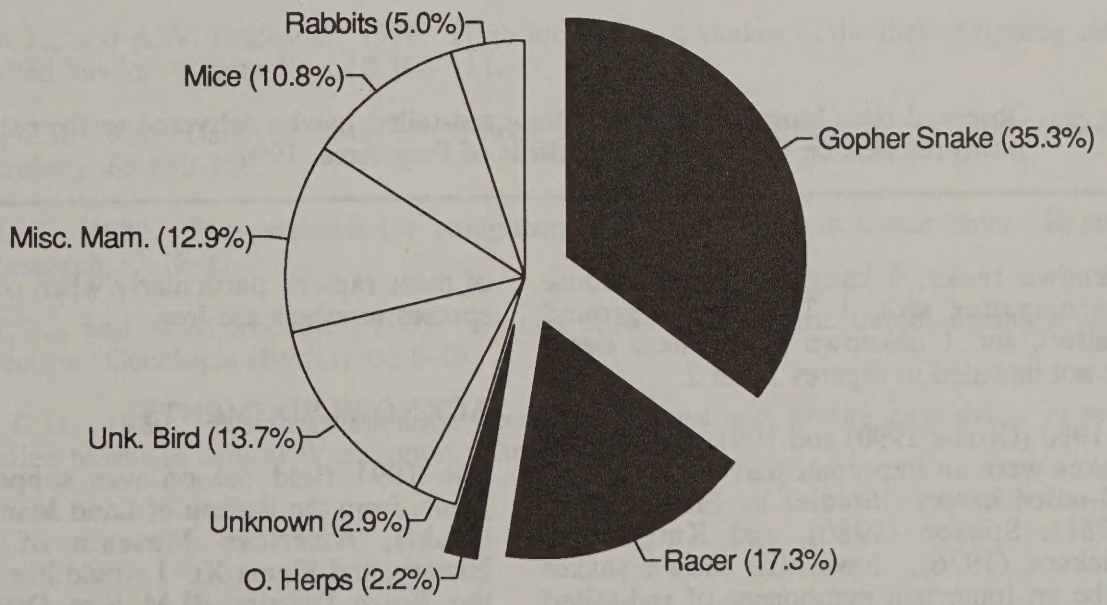


Fig. 1. Observed prey of Pump Draw red-tailed hawks delivered to (or eaten away from) the nest on the Snake River Birds of Prey Area, 1991.

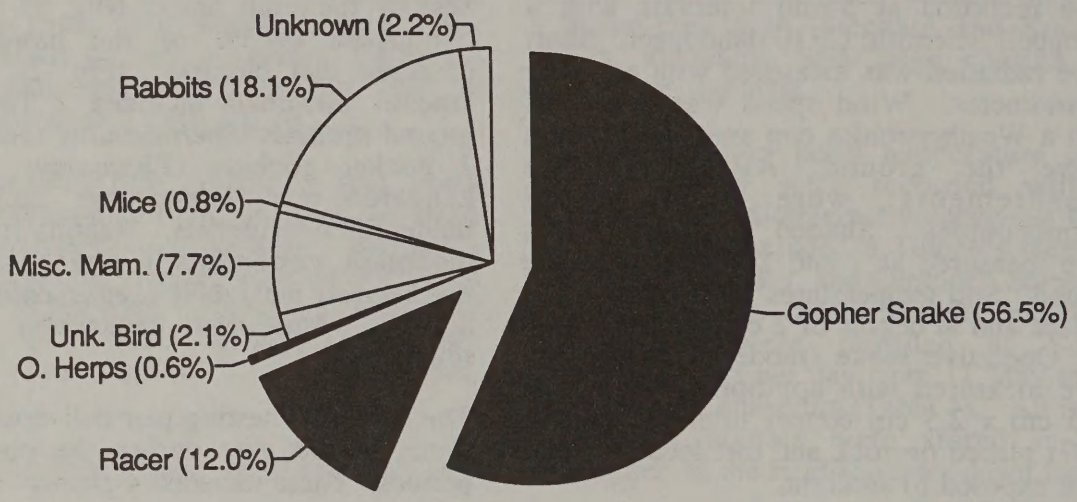


Fig. 2. Observed prey biomass of Pump Draw red-tailed hawks delivered to (or eaten away from) the nest on the Snake River Birds of Prey Area, 1991.

unknown snake, 3 kangaroo rats, 1 mouse (*Peromyscus* sp.), 1 Townsend's ground squirrel, and 1 unknown item. These items are not included in Figures 1 and 2.

In 1990 (Grothe 1990) and 1991, I found that snakes were an important part of the diet of red-tailed hawks. Studies by Fitzner et al. (1981), Stinson (1980), and Knight and Erickson (1976), have also shown snakes to be an important component of red-tailed hawk diet. This may be especially true in the spring when nesting hawks require increased amounts of prey to feed nestlings. The availability of snakes as a primary food item could be crucial to the nesting success of these raptors, particularly when other prey species numbers are low.

## ACKNOWLEDGMENTS

The 1991 field season was supported by grants from the Bureau of Land Management (BLM), American Museum of Natural History, and Sigma Xi. I would like to thank the Boise District BLM Fire Office who allowed my field assistants and me to stay at the Hammett Fireguard Station. The BLM Raptor Research and Technical Assistance Center (RRTAC) provided me with a trailer to use, for which I am grateful.

I am also thankful to the following people for their contributions to my study. RRTAC staff members Michael Kochert, Karen Steenhof, and Gerry Griggs helped me with technical support and living quarters. Dr. Charles H. Trost and Dr. Charles R. Peterson (both of ISU) provided help in obtaining and using equipment. Dr. Trost also allowed me to use his vehicles while in the field. Deborah Scibior brought me supplies and transported snakes to and from ISU. Access to private land was obtained by Robert Bledsoe and Gary Holmes. Mike Dorcas and Vince Cobb performed radio implantation surgeries on the gopher snakes at ISU. Phil Leavitt of Gateway Performance Outfitters of Pocatello, Idaho, assisted with equipment set up. And thanks to Bert and Ernie's in Hammett for just being there.

## PLANS FOR 1991

Data from the 1990 and 1991 field seasons will continue to be analyzed to determine how and if weather has an effect on when snakes are captured by red-tailed hawks. From this analysis, my Master's thesis will be written, and manuscripts will be submitted to scientific journals. I also plan on presenting my results at regional and national raptor, ornithology, herpetology, and ecology meetings.

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# Passerine Surveys on the Snake River Birds of Prey Area

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*Annual Summary*

*We systematically surveyed breeding passerine abundances throughout the SRBOPA using 73 pairs of 200-m radius circular point counts. Points were placed along roads and paired with points about 400 m away from roads but in similar habitat. Grassland species such as horned larks (Eremophila alpestris ) and western meadowlarks (Sturnella neglecta) were most abundant, accounting for 65% and 21%, respectively, of the total number of individuals counted. Although most censuses were conducted in shrub-dominated habitat types, typical shrubland bird species such as sage (Amphispiza belli) and Brewer's sparrows (Spizella breweri), sage thrashers (Oreoscoptes montanus), and others, were much less common, representing only 11% of the total counted.*

*We observed statistically significant habitat associations of the principal grassland and shrubland bird species, both between and within major habitat types. Most of these associations were consistent with previous observations of these species in shrubsteppe ecosystems. However, sage sparrows, which are a characteristically abundant species in sagebrush-dominated habitat throughout the northern Great Basin, occurred at relatively low frequencies in our samples. Except for western meadowlarks, all comparisons between the number of individuals of a species counted at points on- versus off-roads were statistically insignificant ($P > 0.05$). Our data do not suggest why meadowlarks were more likely to be counted at points along roads than points 400 m away.*

## OBJECTIVES

1. To determine the abundance of passerines in various shrub-steppe habitat types.

2. To determine if the abundances of passerine species surveyed along roads are the same as those surveyed in similar habitat away from roadsides.

## INTRODUCTION

Passerine birds are a conspicuous element of Great Basin shrubsteppe habitats (Rotenberry and Wiens 1978, 1980; Wiens and Rotenberry 1981; Smith et al. 1984). Because of several important ecological attributes that these species exhibit, determining their abundances should be an integral feature in any plan to assess the impacts of habitat alteration on raptorial

birds. First, passerines serve as a significant source of prey for certain species of raptors (Marti et al., pers. commun.), and may occasionally be abundant in the diet of individuals of species that are not otherwise commonly considered predators of birds. Clugston (1990), for example, noted that small birds comprised 42 of 98 prey deliveries to a prairie falcon (*Falco mexicanus*) nest. Additionally, because of their own position relatively high in the food chain, and because several species may exhibit rather narrow habitat associations, songbirds may also serve as sensitive indicators of ecosystem disturbance or other habitat changes. Thus, monitoring the distribution and abundance of passerines should be an important element of any long-term management plan on the Snake River Birds of Prey Area (SRBOPA).

Before any monitoring scheme can be implemented, however, its methodology must be verified. A sampling method widely used throughout North America is the U.S. Fish and Wildlife Service's Breeding Bird Survey (BBS; Bystrak 1981). Each survey route is a series of 50 3-min point counts conducted along a 40-km (25-mi) stretch of road. However, a potential bias of surveying from roads is the inevitable edge, or discontinuity in habitat, created by the road itself. The potential difference between the species and their abundance detected from roads and those detected in similar habitat away from roads has only rarely been examined (Keller and Fuller, pers. commun.).

We systematically surveyed breeding passerine abundances at paired on- and off-road sites throughout the SRBOPA. Results of these surveys were used to address 2 basic questions: (1) what are the abundances of passerines in various shrubsteppe habitat types; and (2) are abundances of species surveyed along roads the same as those surveyed in similar habitat but away from roadsides? Answers to the first question will help evaluate differences among habitats in their ability to support prey for raptors, whereas answers to the second will help assess the degree to which typical Breeding Bird Surveys conducted in shrubsteppe habitats represent unbiased estimates of species abundance (e.g., do not over-represent "edge" or "road" species).

## METHODS

### Point Selection

During the April-June 1991 passerine breeding season, we established 73 pairs of points scattered throughout SRBOPA. One member of each pair was located on or within 25 m of a road, and each was matched with a companion point >400 m away from the road but in similar habitat. One point in the pair was selected first from existing vegetation survey transects randomly located throughout SRBOPA (Knick 1990), then matched with a companion. All points were permanently marked and their location determined with a Global Positioning System (GPS). Road types ranged from paved to 2-tracked, well-traveled dirt.

Our initial selection of points represented approximately equal numbers of samples within the general categories of "shrubland" and "grassland." However, we augmented these with additional sites that represented a greater proportion of the entire spectrum of habitat types present on SRBOPA. Habitat within a 200-m radius of each point was classified into a discrete vegetation type based on categories derived from the vegetation mapping effort of Knick et al. (this volume). If necessary, the final location of a sampling point was adjusted to maintain homogeneity of major habitat type within a 200-m radius.

### Survey Methods

At each point, counts were made of all birds (excluding common ravens [*Corvus corax*]

and falconiforms) seen or heard during a 5-min period. For comparison with typical BBS surveys, we noted which individuals were recorded within the first 3 min. The approximate distance to each bird detected was ocularly estimated to a distance of 400 m. However, because 93% (1619 out of 1733 individuals) of all birds seen were detected within 200 m, we truncated the census radius to 200 m for subsequent analysis. All censuses were conducted between 0600 - 1000 hrs on mornings with little wind (0-5 km/hr) and no rain. On days when 2 observers were used, on- and off-road sampling responsibilities were randomly assigned to avoid bias.

### Statistical Analysis

A datum was the number of individuals of a species counted within a 200-m radius of a sampling point (12.57 ha) during 3 min. Differences in species abundances among habitat types were assessed using the Kruskal-Wallis test, whereas differences in species abundances between on- and off-road counts were compared using a paired Wilcoxon test (Sokal and Rohlf 1981). Both non-parametric tests were performed on untransformed counts.

## RESULTS

### General Patterns

We conducted 73 pairs of point-count censuses (146 total censuses) between 30 April and 21 June, 1991. Of these, 27 pairs were in grassland habitat and 46 in shrub habitat. By far the most abundant birds were horned larks; they accounted for 65% of the total number of individuals seen (N = 1534; Table 1). Horned larks were widely distributed throughout the study area, appearing on 138 of 146 point counts. Western meadowlarks were also common, accounting for 21% of the total number of individuals and occurring on over 70% of the counts (Table 1).

Although most censuses were conducted in shrub-dominated habitat types (Tables 1, 2), typical shrubland bird species such as sage and Brewer's sparrows, sage thrashers, rock wrens (*Salpinctes obsoletus*), and lark sparrows (*Chondestes grammacus)*, were much less common, representing only 11% of the total counted (Table 1). Of the group, only Brewer's sparrows occurred on more than 10% of the shrub habitat counts (54 of 92).

### Habitat Associations

Although both horned larks and meadowlarks were observed in all habitat types we censused, they nonetheless differed in their abundances between broad habitat categories, being significantly more numerous in grasslands than shrublands (Kruskal-Wallis test; $\underline{P} < 0.001$, $\underline{P} < 0.05$, respectively). Likewise, the typical shrubland species (Brewer's and sage sparrows, and sage thrashers) also varied between the 2 habitat categories, and were significantly more abundant in shrublands (Kruskal-Wallis test; $\underline{P} < 0.001$, $\underline{P} < 0.05$, and $\underline{P} < 0.05$, respectively).

Although 2 other species, lark buntings (*Calamospiza melanocorys*) and long-billed curlews (*Numenius americanus*, the only non-passeriform censused), are considered typical of grasslands, the small sizes of their samples (Table 1) precluded detecting any differences in their distribution among habitat types, even at a coarse scale. This same problem was evident with white-crowned sparrows (*Zonotrichia leucophrys*) and the other shrubland-typical species.

There were also statistically significant patterns of habitat association within the major categories of shrublands and grasslands. For example, both of the principal grassland species, horned larks and western meadowlarks, showed significant variation in abundance among the 4 grassland types (Table 2) for which we had sufficient samples (Kruskal-Wallis test; $\underline{P} <$

Table 1. Numbers of individuals seen on 3-min, 200-m radius point counts in different habitat types on the SRBOPA, April - June, 1991. Entries are the average number of individuals counted and the number of counts on which they occurred (in parentheses). Values < 0.05 are not shown. "N" is the number of censuses, "Total" is total number of individuals counted. See Table 2 for description of habitat types.

| | I. Shrublands | | | | II. Grasslands | | | | | Grand |
|---|---|---|---|---|---|---|---|---|---|---|
| | I.A.5 (N=22) | I.B.2 (N=22) | I.C.1 (N=26) | Total (N=92) | II.A.1 (N=16) | II.B.1 (N=12) | II.C.1 (N=8) | II.C.2 (N=14) | Total (N=54) | Total (N=146) |
| **Grassland Species** | | | | | | | | | | |
| Horned Lark | 3.6 (20) | 5.2 (20) | 8.0 (26) | 557 (86) | 9.8 (16) | 5.9 (33) | 9.3 (8) | 7.7 (13) | 446 (52) | **1003 (138)** |
| Western Meadowlark | 3.1 (18) | 2.7 (16) | 3.0 (21) | 239 (69) | 1.1 (8) | 2.6 (11) | 3.3 (6) | 0.8 (8) | 97 (37) | **336 (106)** |
| Long-billed Curlew | 0.1 (3) | — | — | 4 (4) | — | 0.1 (1) | — | 0.1 (1) | 4 (3) | **8 (7)** |
| Lark Bunting | — | — | — | — | — | 0.1 (1) | — | — | 1 (1) | **1 (1)** |
| **Shrubland Species** | | | | | | | | | | |
| Brewer's Sparrow | 2.5 (18) | 1.4 (17) | 0.8 (13) | 127 (54) | 0.1 (1) | — | 0.6 (2) | — | 8 (5) | **135 (59)** |
| Sage Sparrow | 0.6 (6) | 0.1 (1) | — | 20 (10) | — | — | — | — | — | **20 (10)** |
| Sage Thrasher | 0.1 (3) | 0.1 (2) | — | 6 (6) | — | — | — | — | — | **6 (6)** |
| Rock Wren | — | — | 0.1 (2) | 4 (3) | — | — | — | — | — | **4 (3)** |
| Lark Sparrow | 0.3 (2) | — | — | 3 (3) | — | — | — | — | — | **3 (3)** |
| White-Crowned Sparrow | 0.2 (1) | 0.2 (2) | — | 9 (3) | — | — | — | — | — | **9 (3)** |
| **Unidentified Species** | — | — | — | 6 (4) | 0.1 (1) | — | — | — | 3 (3) | **9 (7)** |

0.05, $P < 0.01$, respectively). Horned larks reached significantly higher abundances at both ends of the grassland disturbance gradient (native perennial grasses versus exotic annual grasses and mustards; habitats II.A.I and II.C.1, Table 2), and meadowlarks were also more common in communities dominated by exotic annual grasses and mustards. No other species varied significantly among grassland types.

Within shrubland types, horned larks, sage sparrows, and Brewer's sparrows differed significantly (Kruskal-Wallis test; $P < 0.001$,

Table 2. SRBOPA habitat types censused for passerines. Roman numerals represent major habitat type, letters represent degree of disturbance, and arabic numerals represent specific habitat type. Arabic numerals correspond to habitat types described in Knick et al. (this volume), which may be consulted for details of classification.

I. Shrubland

A. Low disturbance

5. high density sagebrush, perennial grasses, native forbs

B. High disturbance

2. medium density sagebrush, perennial grasses, exotic annual grasses

C. Extreme disturbance

1. low density sagebrush, russian thistle

II. Grassland

A. Low disturbance

1. native perennial grasses

B. High disturbance

1. perennial grasses, exotic annuals

C. Extreme disturbance

1. exotic annual grasses, mustards

2. bare ground

$P < 0.01$, $P < 0.001$, respectively.) Both sparrows were most abundant in relatively undisturbed native sagebrush (*Artemisia tridentata*) habitats (I.A.5), with declining numbers as the degree of disturbance increased. Horned larks, on the other hand, showed a strong positive association with the shrubland disturbance gradient, reaching high abundances in areas with exotic russian thistle (*Salsola iberica*) and sparse sagebrush (coverage < 10%; I.C.1).

**On-road and Off-road Comparisons**

Except for western meadowlarks, all comparisons between the number of individuals of a species counted at points on- versus off-roads (Table 3) were statistically insignificant (paired Wilcoxon test; all $P > 0.20$). These comparisons were made both throughout the SRBOPA as a whole and within each of the 2 major habitat types. Although this lack of significance may in part be due to the low statistical power associated with those species that were encountered only infrequently (e.g., occurred on less than 10 counts), such is unlikely to be the case for the more widely distributed horned lark and Brewer's Sparrow.

## DISCUSSION

It was clear that at both coarse and fine scales of classification SRBOPA habitats differed in their ability to support different species (Table 1). Although patterns of distributions of passerine species across habitat types were broadly consistent with previous observations in shrubsteppe ecosystems (Wiens and Rotenberry 1981, Smith et al. 1984), at least 1 of the distributional patterns we observed merits further comment. Sage sparrows, which are a characteristically abundant species in sagebrush-dominated habitat throughout the northern Great Basin, occurred at relatively low frequencies in our samples, being present on only 6 of 22 counts in high-density native sagebrush habitats (I.A.5), and only 10 of 92 counts in shrublands generally (Table 1). We do not know why sage sparrows were absent from otherwise suitable-appearing habitat, given that they are common within 200 km east (T. Rich, pers. commun.) and west of the SRBOPA (Wiens and Rotenberry 1981), but we speculate that it may reflect landscape-level processes. The original large tracts of native sagebrush habitats that historically existed throughout the SRBOPA and the Snake River benchlands (Yensen 1980) have become increasingly fragmented due to disturbance, particularly fire, grazing, introduced exotic annual vegetation, and the complex interactions among those agencies of change. Sage sparrows may require habitat patches of some minimum (but large) size to elicit settlement and territory establishment in the spring, and many of the remaining patches of suitable habitat may be large enough to contain our census sites, but below this minimum. Alternatively, this may simply have been a poor year for sage sparrows due to, say, high over-winter mortality, which represents conditions thousands of kilometers removed from the SRBOPA. To distinguish among these, and other, hypotheses will require extension of these censuses through space and, especially, time.

The absence of a "road effect" (except for meadowlarks) may have several explanations. For one, roads likely represent much less of a habitat discontinuity in grasslands and shrublands than they do in more physiognomically developed woodlands or forests. This may be particularly true in the SRBOPA, where many of the roads are unpaved and have relatively narrow associated rights-of-way. For another, many shrubsteppe species have relatively large territories (Wiens et al. 1985), and may be more able to incorporate small patches of unsuitable habitat than are those with smaller territories. Finally, for several species our sample size is likely too small to generate sufficient statistical power to detect any but the most obvious of

Table 3. Numbers of individuals seen on 3-min, 200-m radius point counts on-versus off-roads in different habitat types on the SRBOPA, April - June, 1991. Entries are the average (and standard deviation) of number of individuals counted. Values < 0.05 are not shown.

| | Shrublands (n=46 pairs) | | Grasslands (n=27 pairs) | | Total (n=73 pairs) | |
|---|---|---|---|---|---|---|
| | on-road | off-road | on-road | off-road | on-road | off-road |
| **Grassland Species** | | | | | | |
| Horned Lark | 5.9 (3.31) | 6.2 (3.98) | 8.1 (3.77) | 8.4 (4.27) | 6.7 (3.62) | 7.0 (4.21) |
| Western Meadowlark | 2.7 (2.25) | 2.5 (2.32) | 2.1 (1.82) | 1.5 (1.78) | 2.5 (2.10) | 2.1 (2.17) |
| Long-billed Curlew | 0.1 (0.25) | -- -- | 0.1 (0.42) | -- -- | 0.1 (0.32) | -- -- |
| Lark Bunting | -- -- | -- -- | -- -- | -- -- | -- -- | -- -- |
| **Shrubland Species** | | | | | | |
| Brewer's Sparrow | 1.4 (1.57) | 1.4 (1.57) | 0.2 (0.79) | 0.1 (0.32) | 0.9 (1.44) | 0.9 (1.41) |
| Sage Sparrow | 0.2 (0.66) | 0.2 (0.70) | -- -- | -- -- | 0.1 (0.53) | 0.1 (0.56) |
| Sage Thrasher | -- -- | 0.1 (0.31) | -- -- | -- -- | -- -- | 0.1 (0.25) |
| Rock Wren | -- -- | 0.1 (0.35) | -- -- | -- -- | -- -- | 0.1 (0.28) |
| Lark Sparrow | -- -- | -- -- | -- -- | -- -- | -- -- | -- -- |
| White-Crowned Sparrow | 0.2 (0.85) | -- -- | -- -- | -- -- | 0.1 (0.68) | -- -- |
| **Unidentified Species** | 0.1 (0.33) | 0.1 (0.33) | 0.1 (0.27) | -- -- | 0.1 (0.30) | 0.1 (0.28) |

differences. Although we originally planned to obtain about twice as many counts as we ultimately did, inclement weather and technical difficulties with GPS reduced opportunities for running censuses.

In conclusion, we strongly recommend continuation of passerine censuses throughout SRBOPA. An enlarged database will allow us to address several important questions relating to habitat associations of shrubsteppe birds. Because we will have multiple samples within the same general habitat type (e.g., big sagebrush, exotic annual grassland, or other shrublands), we can assess intra-habitat (i.e., spatial) variation in abundance. Theory predicts, for example, that different-sized patches of otherwise similar habitat should support different densities of the same species (Pulliam 1988). The management implications, if such turns out to be the case on SRBOPA, are that generalized habitat types with high variance in passerine density likely represent less stable or reliable sources of prey for foraging raptors. As our Geographical Information System-based vegetation map becomes increasingly accurate (Knick et al. this volume), we will be able to address questions relating species distribution and abundances with important landscape features.

Habitat will also be quantitatively characterized at a much finer scale, as each of the existing SRBOPA vegetation transects will be sampled intensively for plant species composition, coverage, and physical structure (Knick 1990). These measurements can be coupled with bird numbers to generate habitat correlations of species' abundances. Comparison of these correlations with those observed elsewhere (e.g., eastern Oregon; Wiens and Rotenberry 1981, Rotenberry 1986) will permit assessment of the regional consistency of a species' habitat selection patterns. These correlations may also be useful in predicting avian responses to changes in vegetation that might occur under different management options.

Finally, these observations can provide the basis for long-term monitoring of passerine populations on SRBOPA. Continued monitoring can provide information on annual variation in species abundances within and between general habitat types, and can be used to detect temporal trends in regional population numbers. Such trends may reflect large-scale habitat loss in either breeding or wintering areas, or changes in vegetation quality and composition due to management or climate change.

## RECOMMENDED PLANS FOR NEXT YEAR

1. Funding should be secured to continue both general passerine surveys as well as evaluation of "road-effects."
2. A subset of sites sampled in 1991 should be selected for sampling in 1992, with the goal of incorporating these locations into a network of sites for long-term passerine monitoring. These sites need not be paired on- and off-road.
3. Additional new pairs of sites should be selected in 1992 using generally the same criteria as in 1991, which will permit both an evaluation of "road-effects" using a larger sample size and the addition of new sites to the monitoring network. New sites should also be selected within the SRBOPA south of the Snake River to increase the range of habitats sampled for bird distributions.
4. The target should be 300 points, of which about 200 should be paired on- and off-road.

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# Energetics, Survival, and Reproductive Endocrinology of Hibernating Townsend's Ground Squirrels (*Spermophilus townsendii*)

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*Annual Summary*

*Experiments are underway that will aid our understanding of the role of hibernaculum temperature on the energy budget and reproductive endocrinology of Townsend's ground squirrels (Spermophilus townsendii). In the field we are monitoring the body temperature of a squirrel to show the feasibility of an experiment monitoring body temperatures and survival of squirrels in various hibernaculum locations. In the laboratory, an experiment is underway to show the effect of hibernaculum temperature on: (1) testosterone and estrogen levels and (2) body condition.*

## OBJECTIVES

1. Determine rate of survival and cause of death for hibernating Townsend's ground squirrels in the Snake River Birds of Prey Area.
2. Determine which physical and biological factors influence over-overwinter survival of Townsend's ground squirrels.
3. Determine the extent to which overwinter mortality affects observed abundance and distribution of Townsend's ground squirrels.
4. Determine how choice of hibernaculum influences reproductive readiness and energy usage.

## INTRODUCTION

Townsend's ground squirrels spend approximately 6 months per year in estivation/hibernation, entering their burrows in June-July, and not emerging until January-February. The rate of survival

during this period is low: Smith and Johnson (1985) estimated it to be 21-38% (although some of the loss may be due to unobserved dispersal). Therefore, variation in overwinter survival has the potential to significantly influence populations of Townsend's ground squirrels.

The determinants of overwinter survival have yet to be elucidated, but it seems likely that because the squirrel must rely on fat stores to finance its 6 months underground, a shortfall in those stores may be an important cause of overwinter mortality (Murie and Boag 1984). Studies of other species of ground squirrel (e.g., Pengelley and Fisher 1961, Twente and Twente 1967, Morrison and Galster 1975, Young 1988) indicate that individual squirrels allow their body temperature to drop to the temperature of their hibernaculum or to 2-3 C above freezing, whichever is highest. Every 1 to 3 weeks, the squirrels arouse, raising their body temperature to the normal, euthermic level for a period of approximately 1 day. Costs of maintenance, which are reduced by approximately 95% compared to standard euthermia, are lower at lower burrow temperatures.

A shortfall in fat reserves could be due to 1 of 2 causes. First, too little fat may have been accumulated prior to immergence. Second, maintenance and thermoregulatory needs may have been excessive, perhaps due to the thermal environment within the hibernaculum.

Reproductive competence upon emergence from hibernation may be affected by hibernaculum temperature as well. Barnes et al. (1987) found that in golden mantled ground squirrels (*Spermophilus lateralis*), *in vitro* stimulation of testicular tissue by luteinizing hormone (LH) results in testosterone secretion at temperatures of 32 C, but not at 5 C. Because testosterone production is dependent on temperature, production should be higher in squirrels in warmer hibernacula, because the temperature during hibernation is higher and because arousal frequency (and therefore total time spent in euthermy) is higher.

The physical environment and the behavior of the squirrel should both be important in determining the thermal environment of the hibernaculum. Important aspects of the physical environment include factors such as slope, aspect, and vegetation cover. Vegetation cover is particularly interesting since it affects both incident solar radiation (Moen 1968, Daubenmire 1972) and convective heat exchange (Porter et al. 1973, Nobel and Geller 1987). Vegetation cover is often severely affected by the activities of humans (e.g., grazing [Yensen 1982] and fires [Yensen 1981, Kochert and Pellant 1986]), and therefore may be the primary factor connecting human impacts with hibernation energetics and survival of Townsend's ground squirrels. Within the conditions available, the exact placement of the hibernaculum will affect its temperature characteristics.

## METHODS

### Laboratory Experiment

Nineteen young-of-the-year and 1 adult *S. townsendii* were captured at the north edge of the Snake River Birds of Prey Area, near Swan Falls Road. Body fat content was determined using a EMSCAN body composition analyzer, and 10 of the squirrels were implanted with temperature sensitive radio-transmitters. Following 2 weeks of acclimation to laboratory conditions, 200 µL of blood was removed from the suborbital sinus of each squirrel to later be analyzed by radio-immunoassay to give baseline testosterone or estrogen levels. Squirrels were then housed at 17 C until mid-October, when half were moved to a cabinet at 21 C and the other half to a cabinet at 17 C. These temperatures are of the same

magnitude as those at 1 m depth at the field site and will be decreased as the season progresses to match field temperatures. The difference between cabinet temperatures is a slight exaggeration of the 2 C difference recorded between the 1-m temperature under a shrub cover and the 1-m temperature in an open habitat. Body temperature is recorded daily; this will give an indication of the frequency with which arousal occurs. On several occasions, temperature has been or will be recorded every half hr for a 24-hr period to show temperature changes at a finer scale. In early January, at approximately the time that arousal would occur, another 200 µL of blood will be taken from each squirrel and analyzed via radio-immunoassay. Body composition will again be measured.

**Field Work**

Field work was conducted to test the feasibility of a full-scale experiment using radio-transmitters to monitor body temperature and survival of a group of squirrels in the field. Four young-of-the-year were captured ≈0.5 km west of Initial Point and implanted with temperature-sensitive radio-transmitters. After release, 3 were never again located (despite extensive searching) probably because of the relatively short (≈15 m) distance over which these transmitters can be detected when underground. The remaining squirrel was monitored hourly over 2 48-hr periods in late summer, and has been monitored occasionally since. Four burrow systems were excavated and mapped. A Campbell Scientific CR21X datalogger was installed at the study site to monitor 2 thermocouple arrays, 1 in a shrubby microsite and 1 in a shrubless, grassy microsite.

PRELIMINARY RESULTS

**Laboratory**

Body composition data have yet to be analyzed, and baseline hormone levels have yet to be determined. Figs. 1 and 2 present examples of the temperature data thus far obtained. Fig. 1 shows the regular occurrence of arousal bouts approximately

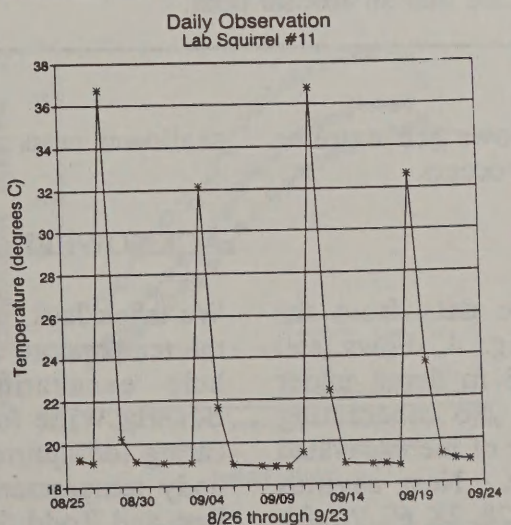


Fig. 1. Example of daily recordings of body temperature from a squirrel held at approx. 17 C, showing regular arousal bouts.

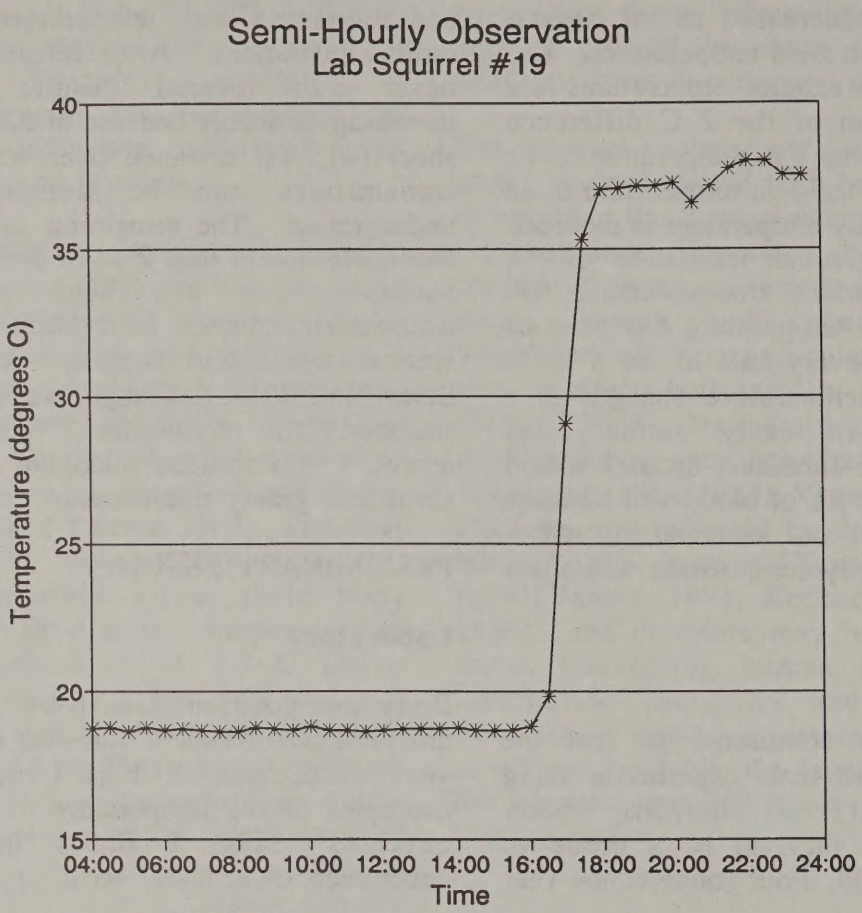


Fig. 2. Example of semi-hourly recordings of body temperature from a squirrel held at approx. 17 C, showing entrance into an arousal bout.

every 5 days. Fig. 2 shows the extreme rapidity with which arousal occurs.

**Field**

Fig. 3 shows temperature data from the squirrel in the field. Fig. 4 shows soil temperatures at 1 and 1.3 m depth under shrubs and in the open. No hibernating squirrels were found in any of the excavated burrow systems, however. Nest cavities were found at depths of 22, 28, 28, 69, 70, 83, 85, and 85 cm. We suspect that the shallower nests are not used for hibernacula.

ACKNOWLEDGMENTS

We thank Jack Small for the help monitoring the temperature of the field squirrel, and for help excavating the burrow systems, Beverly Witte for her help in capturing and caring for squirrels, and for help monitoring body temperatures in the lab, and Corinna Roe and Todd Slichter for help monitoring body temperatures in the lab.

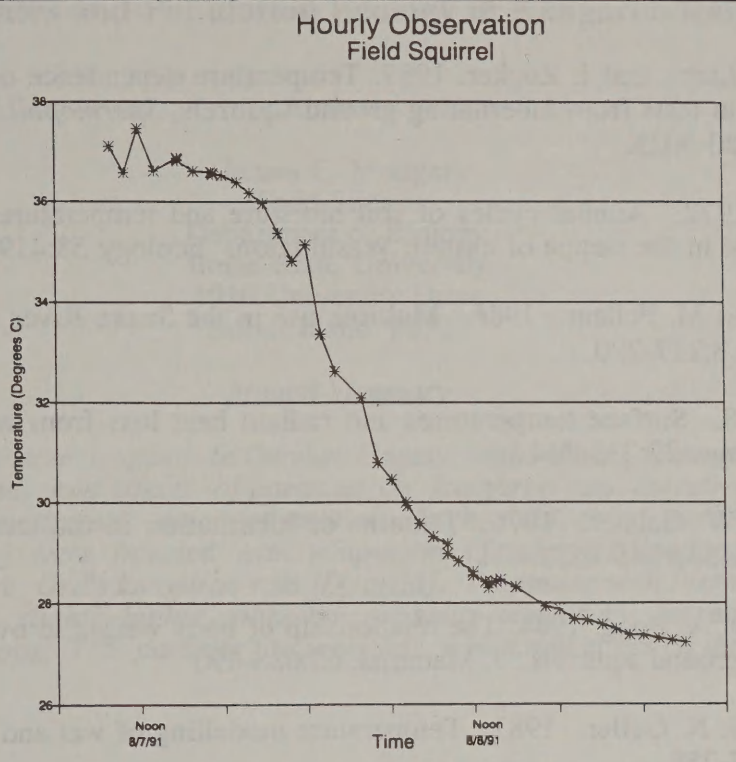


Fig. 3. Example of body temperature recordings from a squirrel in a natural hibernaculum in the field, showing a body temperature drop at the end of an arousal bout.

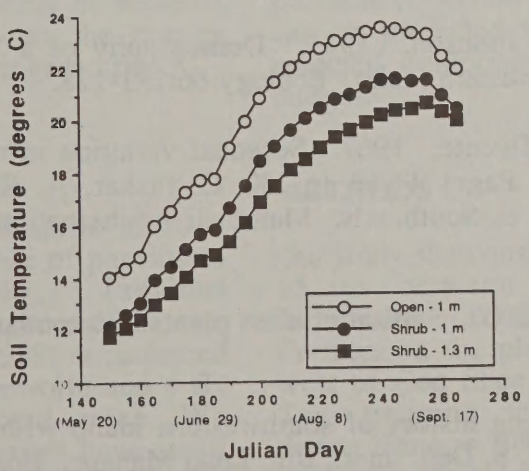


Fig. 4. Soil temperatures measured by thermocouples at 2 microsites, 1 in an open, grassy area and 1 under a shrub. Although temperatures are recorded hourly, for clarity only 1 temperature from each 5th day is depicted.

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# Parasites and Population Ecology in Kangaroo Rats

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*Annual Summary*

*Kangaroo rats were trapped in Owyhee County, Idaho during summer 1990. Parasite loads were quantified, and effects of parasites on kangaroo rats' digestive efficiency were determined using experiments on caged animals. In the field, chisel-toothed kangaroo rats (Dipodomys microps) were infected with whipworms (Trichurus dipodomys) at a higher prevalence than were Ord's kangaroo rats (D. ordii). Treatment with Ivermectin to remove whipworms led to a slightly higher, although probably temporary, increase in digestive efficiency in D. microps. This parasite probably has a minimal effect on the energy budget of these hosts.*

## OBJECTIVES

1. To gather baseline data on the prevalence of selected parasite species in kangaroo rats.

2. To perform preliminary studies to determine the effect of selected parasite species on the energy budget of host kangaroo rats.

## INTRODUCTION

Little empirical evidence exists to allow a critical assessment of the role of parasitism in host population ecology. Previous research in Wisconsin (Munger and Karasov 1989, 1991; Munger et al. 1989) documented effects of 2 parasites, a tapeworm and a fly larva, on host white-footed mice. We showed that: (1) both parasites have small but measurable effects on the host energy budget, (2) we were unable to detect compensations for these perturbations in the energy budgets, leading us to conclude that effects on energy budget were not of major significance, and (3) we were unable to detect effects of either parasite on survival or reproduction.

The goal of the present research is to gather similar evidence on a different system. It is hoped that the methods we are using will eventually provide a means by which probable effects on host population dynamics can be predicted by study of parasites on selected components on the host energy budget.

## METHODS

Our study site consists of a 13 x 13 grid with 15 m between stations, which was established in Rabbit Creek, Owyhee County, on the plain approximately 500 m west of Con Shea road, at T2S R2W S14. Two trapping sessions were conducted during summer 1990, 14-22 June and 15-18 August. Fecal specimens from captured kangaroo rats were analyzed for the presence of parasite eggs by standard centrifugal flotation techniques using saturated sucrose solution (Pritchard and Kruse 1982). Animals captured were

subjected to the following experimental design. Animals were placed in wire-bottomed cages for a 5-day period with a measured amount of millet seed. Fecal pellets were collected, and dry matter digestibility (DMD) was calculated by the formula (Food consumed-Feces produced)/ Food consumed). After this trial half of the infected animals from each species were injected with ivermectin, a drug that kills nematodes. The other half received a control solution. The animals were then subjected to another DMD trial. Another group of naturally uninfected kangaroo rats was subjected to both DMD trials as well.

## RESULTS AND DISCUSSION

Two species of rodents at our site, *Dipodomys ordii* and *Dipodomys microps*, are infected with whipworms (*Trichurus dipodomys*), a nemotode. Interestingly, *Trichurus* occurs at substantially higher prevalence in *D. microps* (Table 1) than in *D. ordii*, a result similar to that of Grundmann (1957). We present 2 possible reasons for this difference. Both reasons rely on 2 facts about the *Trichurus* life cycle: (1) the eggs must embryonate in moist conditions to become infective, and (2) infections occur by ingestion of embryonated eggs, which would occur as a result of contact with feces of an infected host. The first possible explanation is that the feces of *D. microps* have a higher moisture content than do those of *D. ordii* Casual observations indicate this to be true. In addition, higher moisture content would likely result from the higher proportion of vegetation in the diet of *D. microps*. The second possible explanation is that the social structure differs between these species, with *D. microps* individuals visiting burrows (and becoming exposed to parasite eggs) at a substantially higher frequency than do *D. ordii* individuals.

The laboratory digestive efficiency experiments were analyzed with a 3-way analysis of variance (ANOVA). One factor analyzed was the treatment: deinfected (naturally infected but treated with ivermectin) vs. infected (naturally infected but not treated with ivermectin) vs. naturally uninfected. The other 2 factors were species and experimental period (July vs. August). ANOVA was performed on the initial (pre-treatment) dry matter digestibility (DMD), on the final (post-treatment) DMD and on the %-change between the initial and final DMD. This latter measure should be the most sensitive because in expressing treatment effects it takes account of initial differences in DMD among hosts.

Table 1. Infection of 2 species of kangaroo rat with the nematode *Trichurus* sp.

| | *D. microps* | | *D. ordii* | |
|---|---|---|---|---|
| | Infected | Uninfected | Infected | Uninfected |
| June trapping | 10 | 5 | 5 | 39 |
| August trapping | 6 | 9 | 7 | 34 |

Neither the initial nor the final DMD values differed among treatments, nor for any interactions including treatment (Table 2).

There was a significant interaction, however, between treatment and species in their effect on %-change in DMD (Table 2). This interaction was explored using a separate ANOVA on each species, which revealed that treatment had a significant effect on % change in DMD in *D. microps* hosts but not in *D. ordii* hosts (Table 3). This result is depicted in Fig. 1. A Tukey's *a posteriori* multiple sample test revealed that, within *D. microps*, the % change in DMD of the deinfected group differed significantly from the %-change in DMD of both the infected group and that of the uninfected group. These results can be interpreted as showing that the deinfected group had 1.9% higher DMD than the other 2 groups.

If *Trichurus* infection causes a prolonged decrease in DMD in infected hosts, then the DMD of both deinfected and uninfected hosts should have been higher than that of infected hosts. However this was not the case. Only the deinfected group differed from the infected group.

Two possible explanations come to mind. First, infected hosts may compensate for parasite effects via increased gut length, causing their DMD to be similar to that of uninfected hosts. Such an effect has been observed in rats infected with the tapeworm *Hymenolepis diminuta* (Mettrick 1980). Thus, deinfected hosts may be merely enjoying a transitory period following the sudden loss of the parasites, in which the gut has not yet reduced its compensation for parasite effects. Second, the comparison between infected and naturally uninfected

Table 2. F values and probability values (P) from 3-way analyses of variance on effects of species, month, and treatment (deinfected, infected, or uninfected) on dry matter digestibility (DMD).

| | | Dependent Variable | | | | | |
|---|---|---|---|---|---|---|---|
| Source | | Initial DMD | | Final DMD | | %-change in DMD | |
| | df | F | P | F | P | F | P |
| Species | 1 | 2.03 | 0.16 | 0.32 | 0.57 | 0.02 | 0.89 |
| Month | 1 | 0.06 | 0.80 | 12.26 | 0.001 | 0.37 | 0.54 |
| Treatment | 2 | 0.86 | 0.43 | 0.92 | 0.40 | 0.19 | 0.83 |
| Species*Month | 1 | 7.21 | 0.009 | 0.89 | 0.35 | 5.18 | 0.026 |
| Species*Treatment | 2 | 2.74 | 0.07 | 1.64 | 0.20 | 4.95 | 0.01 |
| Month*Treatment | 2 | 3.10 | 0.051 | 0.34 | 0.71 | 0.82 | 0.45 |
| Species*Month*Treatment | 2 | 1.19 | 0.31 | 0.71 | 0.49 | 0.05 | 0.95 |
| Error | 71 | | | | | | |

Table 3. Results from 1-way analysis of variance on the effect of treatment (deinfected, infected, and uninfected) on % change in dry matter digestibility in *D. microps*.

| Source | df | MS | F | P |
|---|---|---|---|---|
| Treatment | 2 | .00106 | 4.64 | .0193 |
| Error | 27 | .000229 | | |

hosts represents a natural experiment (*sensu* Diamond 1986). In such a situation, the uninfected hosts may differ in some significant way (age, condition) from infected hosts, and this preexisting difference may obscure any difference caused by parasitic infection.

Also of interest is the lack of effect in *D. ordii* hosts. This may be due to what appears to be a higher intensity of infection (more parasites per infected host) in *D. microps* hosts: fecal floats of *D. microps* in general contained many more eggs than did floats of *D. ordii* (Munger, personal observation).

One might question the biological importance of the slight, albeit statistically significant, decrease in DMD caused by *Trichurus* infection, even if that effect were more than transitory. Munger and Karasov (1989) showed an effect of similar magnitude resulting from tapeworm infection *(Hymenolepis citelli)* in white-footed mice (*Peromyscus leucopus*). Munger and

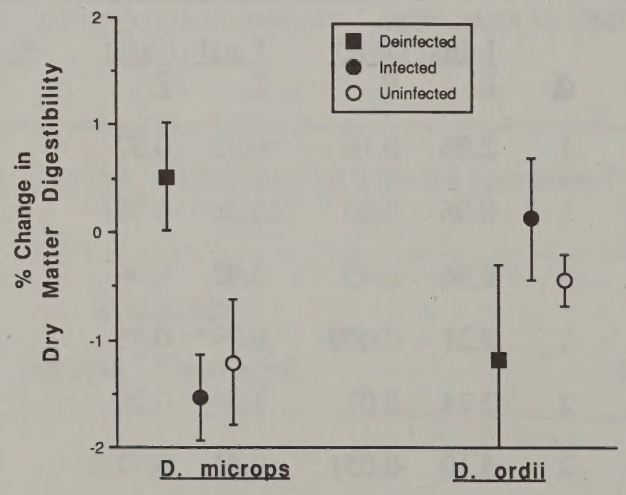


Fig. 1. Effects on variation in parasite load on %-Change in dry matter digestibility. Means +/- SE.

Karasov argued that hosts can easily compensate for such small effects by slight increases in food consumption or decreases in expenditures, and concluded that such effects on DMD are unlikely to affect host energy budgets or to translate through to populational effects. The same conclusion appears to apply to the kangaroo rat-whipworm system.

ACKNOWLEDGMENTS

Kay Kesling was of great help, both in the field and in the lab, helping with the herculean task of separating fecal pellets from uneaten food.

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# Colony Founding in Harvester Ants: Environmental Constraints and Population Implications

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*Annual Summary*

*Our goal is to determine the importance of physical factors in determining the abundance and distribution of colonies of the harvester ant (Pogonomyrmex salinus). Laboratory experiments showed that new queens can only raise brood at temperatures > 28 C or ≤ 35 C and at water potentials that are neither very moist nor very dry. Field measurements showed that, compared to randomly placed points, colonies are found in microsites away from shrubs where they would receive more sunlight, and therefore have sufficiently warm temperatures available for a greater proportion of the year. Field measures confirmed that surface and subsurface temperatures are higher in open microhabitats. These results indicate that on a microhabitat scale, distribution is strongly affected by the presence of shrubs. Future research will attack this question at a macrohabitat scale.*

## OBJECTIVES

1. To determine in the laboratory the temperature and moisture limits to reproductive success in newly-mated harvester ant queens.

2. To determine whether the "distribution" of temperatures and water potentials in the field can account for the distribution and abundance of harvester ant colonies, both on a microhabitat and a macrohabitat scale.

## INTRODUCTION

Ants are a successful and ecologically important group. In desert areas of North America, harvester ants (genus *Pogonomyrmex*) are widespread and may have substantial effects on species composition and abundance in plant and animal communities, both natural and man-altered. Although their community ecology, behavior, and physiology are relatively well studied, little is known about what determines where and at what densities colonies of these ants are found.

The present research project is designed to identify the determinants of density and distribution of colonies of the harvester ant *(Pogonomyrmex salinus)* in southern Idaho. Every year each mature colony typically produces hundreds of winged queens, each of which may found a new colony. However, mature colonies may live for decades, indicating that very few new queens are able to found new colonies. It is reasonable, therefore, to expect that abundance and distribution of mature colonies will in large part depend on factors affecting success at founding new colonies.

In the present research I am focusing on 2 abiotic factors, soil temperature and water potential, both of which (1) should be of critical importance in determining the ability of a new queen to survive and produce brood, and

thereby found a new colony, and (2) vary substantially among sites in the field and therefore have the potential to play a major role in determining density and distribution.

## METHODS

### Laboratory

Lab studies were designed to determine the upper and lower levels of temperature and water potential which limit survival and reproduction by founding queens. During summer 1990, we conducted 2 experiments using newly-mated *Pogonomyrmex salinus* queens, which were gathered on several dates from mating swarms atop Initial Point in the Snake River Birds of Prey Area. In the first experiment, 288 of those queens were divided equally among 24 treatments consisting of all possible combinations of 4 temperatures (25, 30, 35, and 40 C) and 6 water potentials (-125, -250, -500, -1000, -2000, and -4000 kPa) which span soil water potentials typical in desert environments. Desert soils vary from approximately -200 kPa (drained upper limit) to -3500 kPa (lower limit of extraction) (Anderson et al. 1987). Water potential was determined by proximity to solutions containing various concentrations of KCl (Muth 1980). Survival and reproductive activity were ascertained by close inspection approximately every 5 days. The second experiment repeated of the first, except that 38 C was substituted for 40 C. During summer 1991, we conducted a similar experiment, using 4 water potentials (-250, -500, -1000, and -2000 kPa) at each of 4 temperatures (25, 27, 28, and 29 C) with 4 additional water potentials (-62.5, -125, -4000, and -8000 kPa) at 2 other temperatures (30 and 35 C). Sixteen newly-mated queens, collected from Initial Point, were subjected to each of the 32 treatments.

### Field

During summer 1991, we attempted to determine whether the location of ant colonies is correlated with microhabitat characteristics. At a site ca. 0.5 km west of Initial Point, we established 2 plots of 0.5 ha each in an area of mixed sagebrush and grassland. On each plot we marked all active and extinct colonies of *P. salinus* and randomly placed 40 stakes. At each colony and at each random stake, we measured slope; measured percent cover of grass, bare earth, moss, organic duff, gravel, rock, branch, measured the angle traversed by the sun between east and west horizon; measured the angle within 2 m occupied by shrubs; and took a soil sample for sieve and Bouyoucos sedimentation analysis. We also installed a Campbell Scientific 21X datalogger with thermocouple arrays at the site to record soil temperatures at various depths.

## RESULTS

### Laboratory

The following was observed:

(1) At higher temperatures, survival was low; the maximum temperature that can be survived for prolonged periods is < 38 C (Figs. 1, 2).

(2) Although queens laid eggs at 25-38 C, only those at 28-35 C successfully developed into workers (Figs. 1, 2).

(3) Water potential may be limiting as well. No workers were raised at water potentials of -125 kPa or more moist or at -4000 kPa or drier.

### Field

A Multivariate ANOVA was performed to determine which of the measured variables differs significantly between colony locations and random locations on 1 of our study plots. We stress that this analysis is preliminary; e.g., soil factors are not included. As indicated by Tables 1 and 2, 2 of the cover variables (moss and branch) were significantly lower at colony sites than at random sites, and 1 cover variable (gravel) was significantly higher at colony sites. In addition, colonies have a longer exposure to the sun each day (Fig. 3) and a lower proximity to shrubs (Fig. 4) than do random sites. Fig. 5 shows soil temperatures during 1 day and illustrates that soil temperatures are lower under bushes than

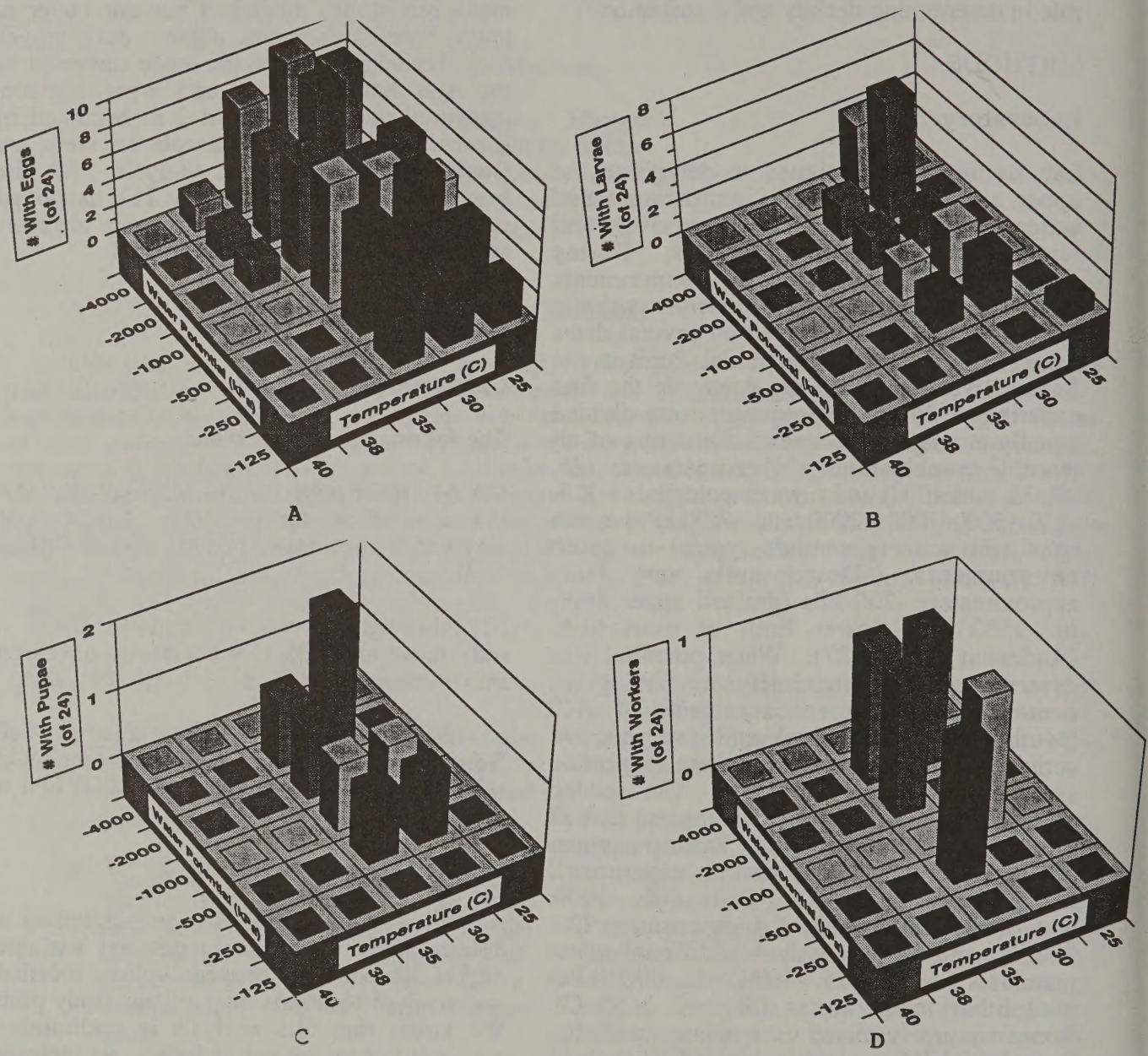


Fig. 1. Effects of temperature and water potential on ability to raise brood in *P. salinus* queens: Summer 1990 date. A, B, C, D: # of queens producing eggs, larvae, pupae, and workers, respectively.

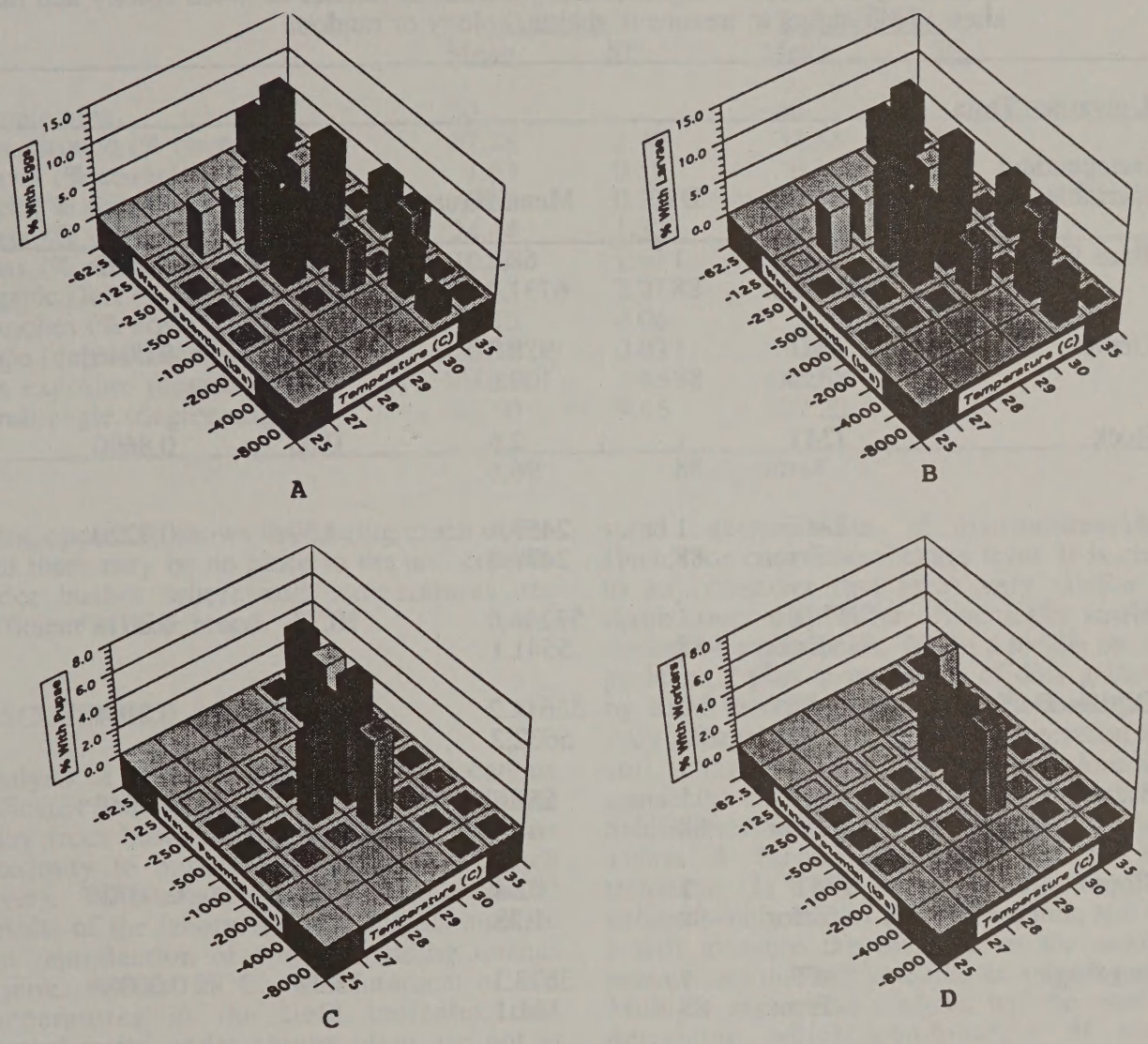


Fig. 2. Effects of temperature and water potential on ability to raise brood in *P. salinus* queens: Summer 1991 data. A, B, C, D: # of queens producing eggs, larvae, pupae, and workers, respectively.

Table 1. Results from multivariate analysis of variance (SAS PROC GLM). The P-values should be evaluated against a Bonferroni adjusted significance level of 0.00512 to control Type I error; * signifies a significant difference between colony and random sites. TMT refers to treatment, that is, colony or random.

Univariate Tests

| Independent Variable | Source | DF | Mean Square | F | P |
|---|---|---|---|---|---|
| Bare Earth | TMT | 1 | 68.4 | 0.01 | 0.9199 |
| | Error | 88 | 6731.8 | | |
| Gravel | TMT | 1 | 928.8 | 8.47 | 0.0046* |
| | Error | 88 | 109.6 | | |
| Rock | TMT | 1 | 2.6 | 0.03 | 0.8690 |
| | Error | 88 | 96.6 | | |
| Grass | TMT | 1 | 2459.3 | 0.99 | 0.3220 |
| | Error | 88 | 2479.0 | | |
| Moss | TMT | 1 | 57246.0 | 10.33 | 0.0018* |
| | Error | 88 | 5541.1 | | |
| Organic Duff | TMT | 1 | 38614.2 | 6.86 | 0.0104 |
| | Error | 88 | 5632.2 | | |
| Branch | TMT | 1 | 557.8 | 8.66 | 0.0042* |
| | Error | 88 | 64.4 | | |
| Slope | TMT | 1 | 0.34 | 0.27 | 0.6072 |
| | Error | 88 | 1.28 | | |
| Sun Angle | TMT | 1 | 3673.1 | 12.09 | 0.0008* |
| | Error | 88 | 131.1 | | |
| Shrub Angle | TMT | 1 | 159424.2 | 15.43 | 0.0002* |
| | Error | 88 | 10331.5 | | |

Multivariate Analysis of Variance

Wilks' Lambda = 0.698, $F_{10,79} = 3.4138$ $\underline{P} = 0.0009$

Table 2. Means and standard errors of 10 variables subjected to Multivariate Analysis of Variance. All data from 1 0.5-ha plot 0.5 km west of Initial Point.

| | Colonies | | Random Sites | |
|---|---|---|---|---|
| | Mean | SE | Mean | SE |
| Sample size | 50 | | 40 | |
| Bare Ground (% cover) | 37.28 | 2.40 | 37.64 | 2.48 |
| Gravel (% cover) | 1.63 | 0.39 | 0.34 | 0.11 |
| Rock ( % cover) | 0.62 | 0.27 | 0.68 | 0.33 |
| Grass (% cover) | 24.44 | 1.32 | 22.34 | 1.69 |
| Moss (% cover) | 10.54 | 1.67 | 20.70 | 2.85 |
| Organic Duff (% cover) | 25.15 | 2.27 | 16.82 | 2.15 |
| Branches (% cover) | 0.15 | 0.06 | 1.15 | 0.37 |
| Slope (degree from horiz.) | 0.38 | 0.03 | 0.41 | 0.04 |
| Sun exposure (degree angle) | 168.48 | 1.66 | 143.68 | 7.71 |
| Shrub angle (degree angle) | 42.50 | 9.45 | 127.20 | 21.04 |

in the open, and shows that during much of the year there may be no place in the soil column under bushes where soil temperatures are sufficient to raise brood.

## DISCUSSION

Analysis of characteristics of colony locations indicates that colonies are typically found away from bushes (high amount of sun, low proximity to bushes, low moss and branch cover). What might have caused this result? Results of the laboratory experiments indicate that reproduction of newly founding queens requires at least 28 C. Measurement of soil temperatures in the field indicates that microclimates under shrubs often are not at temperatures sufficient to sustain reproduction by harvester ant queens. These results indicate that on a microhabitat scale, colonies tend to be limited to areas receiving sufficient sunlight to provide sufficient warmth for reproduction by queens.

Still remaining, however, is the need to understand determinants of distribution and abundance on a macrohabitat level. It is clear to any observer that areas very similar in shrub cover may differ dramatically in their density of ant colonies. To get a handle on this problem, I plan to make use of data gathered by BLM workers at the Snake River Birds of Prey Area, who have measured vegetation and soil characteristics of several hundred transects, each 400-m long, in a study of habitat relations of ground squirrels. I will assess 2 further characteristics of the transects: (1) I will count all colonies of *P. salinus* within 5 m of the transect line, and (2) I will measure the distance to the nearest promontory that has potential as a mating site. Multiple regression analysis will be used to determine which combination of these variables best explains variation in colony density.

## ACKNOWLEDGMENTS

Kay Kesling's help in setting up the 1990 laboratory experiment is greatly appreciated.

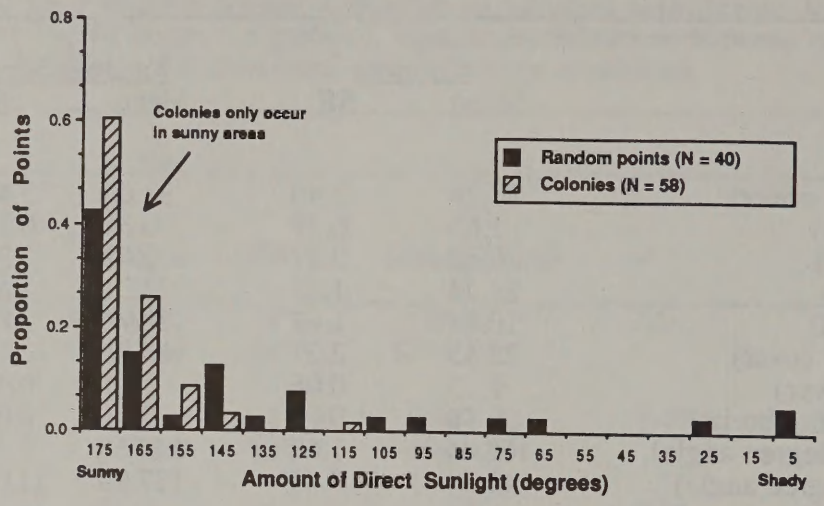


Fig. 3. Distribution of colonies and random points as a function of amount of direct sunlight received, measured as the angle from the east horizon to the west horizon.

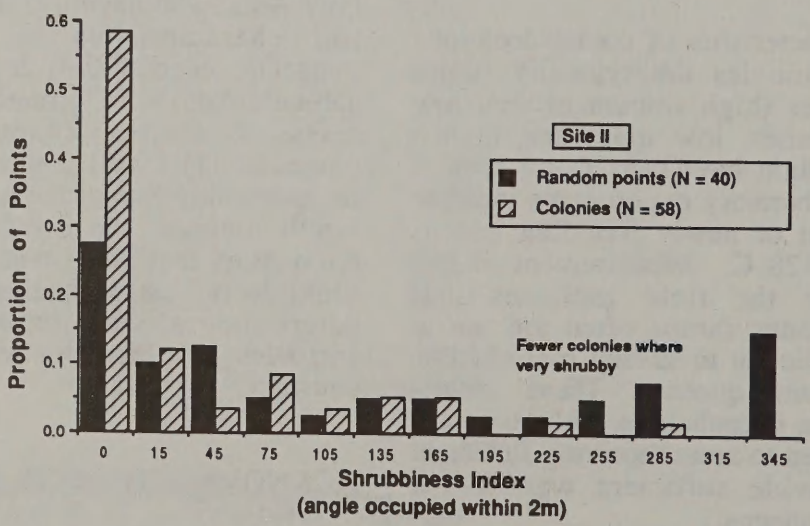


Fig. 4. Distribution of colonies and random points as a function of shrubbiness, measured as the angle within 2 m of the point occupied by shrubs.

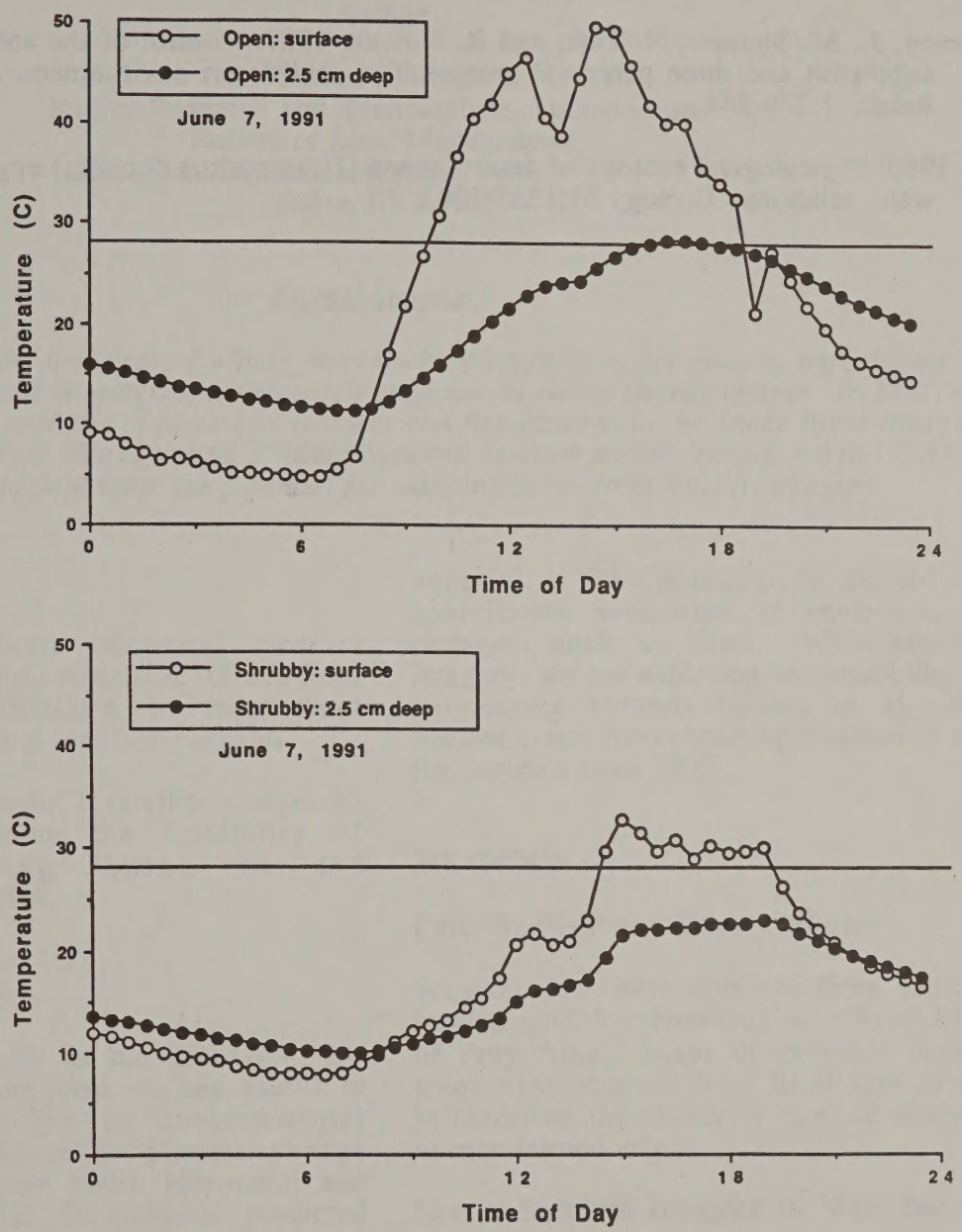


Fig. 5. Soil temperatures recorded using thermocouples and a Campbell Scientific CR21X datalogger at a site 0.5 km west of Initial Point. The top graph is from a grassy shrubless microsite; the bottom graph is from a microsite under the canopy of sagebrush. The horizontal lines are at 28 C, the minimum temperature at which brood were raised in the laboratory (see Figs. 1 and 2).

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# Weather and Fire Pattern in the Snake River Birds of Prey Area

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*Annual Summary*

*This was the first year of a long-term study of vegetation, fire pattern, and climate in the Bureau of Land Management's research program on global climate change. In 1991, we collected data for analysis of historical weather and fire patterns in the Snake River Birds of Prey Area (SRBOPA). We obtained 3 Multi-Spectral Scanner scenes (spring and fall 1987, and spring 1988) to determine the potential for mapping burns from satellite imagery.*

## OBJECTIVES

1. To obtain historical weather data from stations ≤ 100 km from the SRBOPA to reconstruct historical weather patterns.

2. To obtain 3 satellite images to determine the feasibility of mapping burns in the SRBOPA.

## INTRODUCTION

Natural areas, such as the SRBOPA, are important for long-term studies useful in interpreting changes in environmental communities relative to climate change (Burke and Kiester 1990, Herrmann and Stottlemyer 1991). In addition, predicted losses in habitat productivity and increased aridification are likely to be strongest in the zone between arid and semi-arid regions (Schlesinger et al. 1990), which includes the SRBOPA.

The use of satellite imagery and geographical information systems as a tool (Podolsky and Morehouse 1990) are now available in the SRBOPA (Knick et al., this volume). This potential is needed for quantitative evaluation of environmental changes, such as fires. With satellite imagery, we are exploring the possibility of delineating habitats (Knick et al., this volume), and reconstructing vegetation and fire patterns since 1972.

## METHODS

### Past Weather and Burn Patterns

Weather data were obtained from stations located ≤100 km from the Snake River Birds of Prey Area. Maps of previous burned areas were obtained from BLM files to use in assessing the ability of satellite imagery to map burned areas.

### Use of Satellite Imagery to Map Burned Areas

Image Preparation.--Three Landsat images of the SRBOPA were obtained from spring and fall 1987 and spring 1988. Images were georeferenced to the UTM projection system using ground control points selected from 1:24K USGS quads and the images. Spectral and spatial aspects of the satellite images were enhanced by using ratios of different

spectral band widths and edge filters.

## RESULTS AND DISCUSSION

### Past Weather and Fire Patterns

Weather data were obtained for 19 sites located from 0-100 km from the SRBOPA (Table 1). Temperature (daily min., max., avg.) and precipitation data were recorded since 1904 for the earliest records. Records of fire incidence were documented since 1952.

### Use of Satellite Imagery to Map Burns

We obtained 3 Multi-Spectral Scanner satellite images (spring and fall 1987, spring 1988) for analysis of burns in the SRBOPA. A contract was established with Idaho Department of Water Resources to process the imagery and delineate boundaries of burned areas.

## PLANS FOR NEXT YEAR

### Past Weather and Fire Patterns

Our analyses will first document trends and then explore potential relationships in weather, vegetation, and fire patterns. We will analyze weather data to establish historical trends that can be related to vegetation and fire pattern (Munn 1988). We also will develop a climate model by contouring weather data and elevational data to establish temperature and precipitation patterns for the SRBOPA.

### Use of Satellite Imagery to Map Burns

We will determine the potential of mapping burns from satellite imagery. The 3 scenes will be analyzed independently to assess how the different seasonal characteristics of the vegetation influence burn discrimination. Burns will be delimited using image interpretation techniques with appropriate ancillary data, such as soils or vegetation maps, to facilitate the process.

Field surveys of burn sites in different preburn habitats (e.g. sagebrush [*Artemisia tridentata*], winterfat [*Ceratoides lanata*], or cheatgrass [*Bromus tectorum*]) or different burn frequency (e.g., repeated burn versus single burn) will be used to facilitate the image interpretation. The purpose of the field visits will be to compare vegetation coverage in burned and adjacent unburned areas, map boundaries of burns using a Global Positioning System, and inspect regions where results from satellite imagery are inconsistent with field verifications.

Statistical methods will be developed to assess the accuracy of mapping burns using satellite imagery. This methodology will include a sampling grid of burned and unburned areas that will be verified during the field surveys or by ancillary research projects.

## ACKNOWLEDGMENTS

M. Vinson, Bureau of Land Management, provided data from weather stations. B. Krambeer and A. Morse, Idaho Dep. of Water Resources, analyzed the satellite imagery. M. N. Kochert, K. Steenhof, J. T. Rotenberry, and T. J. Zarriello assisted with various aspects of this study. Funding was provided by the Bureau of Land Management Global Climate Change Program.

Table 1. Location and dates of weather data for stations used in analysis of historical trends in temperature and precipitation.

| Station | Latitude | Longitude | Date | |
|---|---|---|---|---|
| | | | Start | End |
| ANDERSON DAM | 43.21 | 115.281 | 1 Aug 1948 | 31 Dec 1989 |
| ARROWROCK | 43.21 | 115.28 | 1 Jun 1916 | 31 Dec 1989 |
| BOISE 7N | 44.00 | 116.12 | 1 May 1973 | 31 Dec 1989 |
| BOISE WSFO | 43.34 | 116.13 | 1 Jan 1940 | 31 Dec 1989 |
| BROWNLEE | 44.50 | 116.52 | 14 Jun 1966 | 31 Dec 1989 |
| BRUNEAU | 42.53 | 115.48 | 1 Jun 1962 | 31 Dec 1989 |
| CALDWELL | 43.40 | 116.41 | 8 Oct 1940 | 31 Dec 1989 |
| CENTERVILLE | 43.54 | 115.511 | 1 Nov 1949 | 30 Sep 1989 |
| DEER FLAT | 43.55 | 116.45 | 14 Mar 1916 | 31 Dec 1989 |
| EMMETT | 43.52 | 116.28 | 1 Aug 1948 | 31 Dec 1989 |
| GARDEN VALLEY | 44.04 | 115.55 | 1 Aug 1948 | 31 Dec 1989 |
| GRAND VIEW | 43.00 | 116.08 | 1 Apr 1933 | 31 Dec 1989 |
| KUNA | 43.34 | 116.24 | 1 Aug 1948 | 19 Feb 1966 |
| MOUNTAIN HOME | 43.08 | 115.42 | 1 Aug 1948 | 31 Dec 1989 |
| NAMPA 2NW | 43.36 | 116.35 | 1 Aug 1948 | 31 Jan 1960 |
| PARMA | 43.48 | 116.57 | 7 Nov 1922 | 30 Sep 1956 |
| REYNOLDS CRK | 43.12 | 116.45 | 1 Dec 1961 | 31 Dec 1989 |
| SILVER CITY | 43.01 | 116.49 | 1 Nov 1978 | 31 Dec 1989 |
| SWAN FALLS | 43.15 | 116.231 | 1 Aug 1948 | 31 Dec 1989 |

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# 1991 Monitoring Studies on Greenstrip Projects in the Snake River Birds of Prey Area

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*Annual Summary*

*Monitoring of greenstrip projects is continuing with data collection at 27 study sites on 8 greenstrip projects. In addition, 2 new study sites were established on 2 greenstrip projects during the 1991 field season. Recruitment of a native shrub is occurring at a faster rate than that of an exotic shrub on a disturbed site.*

## OBJECTIVE

To monitor establishment and persistence of plants used to establish strips of fire resistant vegetation (i.e., greenstrips) in the Snake River Birds of Prey Area (SRBOPA).

## METHODS

Two similar study procedures are used to determine if objectives are being met. Most greenstrip projects are monitored with a procedure that combines cover, density, phenology and frequency data collection. This procedure, called "Freqdens," is described in a previously published report (Pellant 1989).

Prior to the initiation of the "Freqdens" procedure in 1989, selected greenstrip projects were monitored using a pace transect. The same vegetation sampling procedures are utilized with the pace transect and "Freqdens" techniques. The primary difference is the use of 5 short belt transects with "Freqdens" versus the use of 1 long pace transect in the pace transect technique. Closeup and general view photographs are taken on all studies.

## RESULTS AND DISCUSSION

During the 1991 field season, 27 study sites on 8 greenstrip projects were visited and monitoring studies re-read. One new study site was established on the Cinder Cone greenstrip southeast of Cinder Cone Butte; the other new study site was established on the Dorsey greenstrip northeast of Dorsey Butte. The new Cinder Cone study site will monitor vegetation on that portion of the greenstrip reseeded in 1990. The new Dorsey study site will monitor vegetation in an area reseeded in 1991. Both the original Cinder Cone and Dorsey greenstrip seedings were determined to have failed as a result of a multiple year drought.

Two study sites established in 1990 on an experimental greenstrip near Simco Road were re-sampled in 1991. A new site preparation and seeding machine (disk chain) was used to seed a crested wheatgrass (*Agropyron cristatum*) and forage kochia (*Kochia prostrata*) mixture in 1986. Forage kochia is an introduced half-shrub that is very competitive with cheatgrass (*Bromus tectorum*) and retains fire resistance throughout the summer. These studies document the competitive

interactions between seeded and native species along 4 160-m transects. The transects originate at the greenstrip boundary and run into adjacent rangeland.

Numbers of mature forage kochia and shadscale *(Atriplex confertifolia)*, the dominant pre-fire shrub, decreased by 28% and 20%, respectively, from 1990 to 1991 (Table 1). Drought conditions and record low winter temperatures were probably responsible for mature plant mortality. Relative recruitment of each shrub can be compared by dividing number of seedlings by the total number of mature plants. Relative recruitment values of 0.095 seedlings per mature shadscale plant were 2.5 times greater than the 0.038 seedlings per mature forage kochia plant. Apparently, shadscale is better adapted to establish on this site given the harsh climatic conditions of the 1991 growing season.

Detailed evaluation reports for each greenstrip project in the SRBOPA are nearing completion. These reports include site preparation and seeding descriptions, management actions, climatic information and monitoring data. Monitoring of selected greenstrip projects in the SRBOPA will continue in 1992.

## ACKNOWLEDGMENTS

C. Hall assisted in the collection and compilation of 1991 monitoring data.

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Table 1. Forage kochia and shadscale survival and recruitment (nos./ha) in 1990-91.

| | Forage kochia | | Shadscale | |
|---|---|---|---|---|
| | Seedling | Mature | Seedling | Mature |
| 1990 | 0.0 | 4,544.8 | 24.7 | 1,951.3 |
| 1991 | 123.5 | 3,260.4 | 148.2 | 1,556.1 |

# Environmental Monitoring in the Idaho Army National Guard Orchard Training Area

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*Annual Summary*

*Two hundred sixty-four permanent land condition-trend vegetation/soil monitoring (LCTA) plots established in 1989 and 1990 were monitored, and small mammals were inventoried on selected LCTA plots. LCTA plots south of the livestock drift fence were monitored twice, once in early spring and once in summer. One additional control LCTA plot was established on BLM land within 3.2 km of the Orchard Training Area (OTA) boundary. LCTA special-use plots were established on Lepidium papilliferum sites. Plot locations were ground-truthed with a Trimble Pathfinder global positioning system. We initiated efforts to monitor reptiles in the OTA. Several plant species not previously collected in the training area were identified and archived in herbaria.*

## OBJECTIVE

To assess and monitor the land condition and mammal and reptile populations in the Orchard Training Area in order to minimize the impacts of National Guard training.

## METHODS

### Vegetation/soils monitoring

A 50th control plot location was selected and monitored using the LCTA method (U.S. Army Corps of Engineers 1987); this is a special-use plot, located in the 1980 Swan Falls big sage grazing exclosure.

In addition, 15 new special-use LCTA plots were established inside the OTA, to monitor populations of a federal candidate 2 plant species, *Lepidium papilliferum* (hereafter called LEPA). The LCTA method was used to establish and monitor these LEPA plots, with the following modifications:

A cluster of LEPA having at least 10 plants was found. The 50-m stake of the LCTA plot was placed in the center of the small clearing where the cluster of LEPA plants was located. The line azimuth of the plot transect was determined from a random number table. An extra soil sample from each plot was taken (besides the 2 samples per plot

taken under the LCTA method); the third sample was taken 1 m to the right (facing the 100-m stake) of the 50-m stake. The LEPA plants in the cluster around the 50-m stake were censused by attaching a second tape to the 50-m stake and counting all LEPA plants within a 10-m radius. We recorded the number of plants, and the number of those that were in bud or in bloom. We recorded this information in the "Comments" section of the Land Use portion of the LCTA software or form. We photographed the LEPA cluster by taking color 35-mm photos from 40 m and from 60 m on the tape, looking toward the 50-m stake. On plots with dense, tall sagebrush (*Artemisia tridentata)*, we took additional photos from the 45-m and 55-m tape locations. Also, LEPA plants were counted on 4 1.6-km walking transects, monitored in early June.

To document livestock use of plots in the winter grazing allotment, we attempted to monitor all non-special-use LCTA plots south of the livestock drift fence between 1 March and 15 May 1991. All but 6 of these plots were monitored. This data set is called 1991 EARLY. All EARLY plots were again monitored between 10 June and 1 October 1991, during the regular monitoring of all LCTA plots.

On LCTA plots established in 1989 and 1990, belt transects were not sampled in 1991, with the exception of the shrub transplant special-use plots established in 1990. Belt transects were sampled on the control plot and the special use-plots established in 1991. Shrub belt transects were monitored using the methods outlined in this section of the 1990 Birds of Prey annual report (Quinney 1990). All native shrubs were counted on 1990 transplant special-use plots, using the methods reported in the 1990 Birds of Prey annual report (Quinney 1990).

Plant species not previously recorded from the OTA were collected and identified.

A more detailed explanation of the LCTA methods used in the Orchard Training Area can be found in the U.S. Army Land Condition Trend Analysis (LCTA) Field Methods manual (U.S. Army Corps of Engineers 1987).

Using the Geographic Resources Analysis Support System software's random function (Warren et al. 1990), map coordinates for 50 photopoint locations in the polygon formed by Range Road and the livestock drift fence were determined. This is the area that will be most affected by changes in military and livestock use after some firing ranges are shifted south of the drift fence in the future. Photopoints were marked in the field with a 46-cm (18-in) steel stake pounded into the ground with only a 2.5-5 cm left exposed. Photopoints were monitored between 15 April and 15 May, the time of maximum native vegetation greenup. At each photopoint, 35-mm color photographs were taken facing outward from the stake at 0 degrees, 90 degrees, 180 degrees, and 270 degrees.

**Small mammal and reptile monitoring**

The LCTA plots on which small mammals were snap-trapped in 1990, were also trapped in 1991, using methods described in the 1990 annual report. Beginning in mid-June and ending in late October, we trapped 60 plots.

In June and July, the 60 mammal-trapping plots were censused for Townsend's ground squirrel (*Spermophilus townsendii,* hereafter TGS) and badger (*Taxidea taxus*) holes, using the method described in the 1990 annual report.

In 1991, we attempted to monitor OTA

reptiles. The standard LCTA reptile monitoring method (Tazik et al. 1991) was implemented at LCTA plots 112 and 143. We used a triad arrangement of drift fences made of metal flashing held in place by stakes, and buried buckets. The flashing was 20 cm (8 in) wide, buried 5-8 cm (2-3 in) in the ground and held in place with metal stakes. In the center, and at the end of each of the 3 arms of the triad, a 19-liter (5-gal) plastic bucket was buried with the rim flush to the ground. We established each pitfall triad within 75 m of the LCTA plot's stake 1, on a random azimuth in the 180-degree arc away from the LCTA plot's stake 1. Each site was trapped on 4 consecutive mornings. Traps were checked every morning before 1000 hrs. These methods are detailed in the revised LCTA manual (Tazik et al. 1991). The perimeter of a site being sampled was marked with wire-standard flags to indicate to soldiers that the area was to be avoided. Trapped animals were released on the sites. At the end of each trapping session, triads were removed from the sites and the pits in the soil filled in.

## RESULTS

### Vegetation/soils monitoring

In 1991, 279 LCTA plots were inventoried. Non-special-use plots south of the drift fence were monitored twice. One 1989 plot, plot 89, was not monitored in 1991 because it had been annihilated by multipurpose range complex construction; it was dropped from the list of plots. One additional control plot was created, and 15 special-use LEPA-monitoring plots were established in the OTA in big sagebrush habitats. Analysis of LCTA-plot soil samples by the U.S. Soil Conservation Service National Soils Laboratory is still under way. On the 8 native shrub transplant sites established in 1990, all shrub seedlings were counted. Walking surveys were done to provide a rough estimate of 1991 LEPA numbers in the OTA; approximately 5,000 living individuals were counted. A Trimble Pathfinder global positioning unit (without reference to a base station) was used to geolocate LCTA plots, OTA weather stations, and completed photopoints. Most of these locations were established during the winter of 1990-91, when the U.S. Department of Defense signal scrambling was turned off. LCTA data collected are on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, and at the Idaho Army National Guard Department of Engineering, Gowen Field, Boise, Idaho.

Information collected on LEPA in 1991 is on file in Boise, Idaho, at the Army National Guard Department of Engineering, with Dr. Roger Rosentreter, Idaho State Office of the Bureau of Land Management, and with Robert Moseley, Idaho State Department of Fish and Game. Plant species recorded for the OTA as of May 1991 are listed in Appendix A; herbarium voucher specimens have been archived in the herbarium of Colorado State University, Fort Collins, Colorado. Of special note in 1991 was the finding of *Agropyron spicatum* (Pursh) Scribn. & Sm., blueblunch wheatgrass, in the OTA.

Because of time, staffing, and firing-range use constraints, only 6 of the 50 north-impact area photopoints were established in the field in 1991. Establishment, geolocating, and monitoring of all points is planned for 1992.

### Small mammal and reptile monitoring

The 1991 mammal survey resulted in the capture of the following species in the

Orchard Training Area: *Tamias minimus, Dipodomys microps, Dipodomys ordii, Onychomys leucogaster, Perognathus parvus, Peromyscus maniculatus, Neotoma cinerea, Reithrodontomys megalotis, Sylvilagus nuttallii,* and *Spermophilus townsendii.* Added to the OTA mammal species list in 1991 was *Antilocapra americana*; a female pronghorn was sighted in the vicinity of Christmas Mountain on several occasions in March. 1991 mammal-capture data, when compiled, will be filed in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, at the Idaho Department of Fish and Game, and at the Idaho Army National Guard Department of Engineering, Gowen Field, Boise, Idaho.

Sixty TGS/badger hole-count transects were sampled during June and July 1991. TGS and badger hole-count data, when compiled, will be on file in the office of the U.S. Army Corps of Engineers Research Laboratory, Champaign, Illinois, and at the Idaho Army National Guard Department of Engineering, Gowen Field, Boise, Idaho.

Black-tailed jackrabbit (*Lepus californicus*) censusing was done as part of the BLM Snake River Birds of Prey Area monitoring effort, and OTA results are included in the section of this annual report that reports jackrabbit abundance in the Snake River Birds of Prey Area.

This was a pilot year for OTA reptile monitoring. The standard LCTA reptile pitfall traps were not effective; only invertebrates were caught in 8 days of pitfall trapping. Next year, we will use drift fences with wire-box traps after the method of Diller and Johnson (1982). Three nights of road-driving and rocky-outcrop searching, plus a number of daytime hand captures yielded the following OTA species in 1991: *Uta stansburiana, Phrynosoma platyrhinos, Sceloporus graciosus, Sceloporus occidentalis, Gambelia wislizenii, Pituophis catenifer, Coluber constrictor*, and *Crotalus viridis*. Seen but not captured was *Cnemidophorus tigris*. We had planned to collect ectoparasites from the reptiles for the Idaho State Veterinary Laboratory, but no ticks or mites were found on any of the captured animals.

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